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Parasites of the Oriental Fruit Moth in the Eastern United States

By H. W. ALLEN,[1] *entomologist, Entomology Research Division, Agricultural Research Service*

From 1930 to 1939 the survey of parasites of the oriental fruit moth (*Grapholitha molesta* (Busck)) in the area from Massachusetts to Georgia and west to Illinois, Kansas, and Texas was a major project of the U.S. Department of Agriculture's Oriental Fruit Moth Investigations at Moorestown, N.J. This work was supplemented by more limited surveys during several seasons from 1940 to 1957. The data obtained are summarized in this publication. Since recognition of species is essential, keys have been prepared when the pertinent characters were fairly obvious. In preparing these keys the publications of the Department and the U.S. National Museum have been followed whenever feasible.

The North American parasites and hyperparasites of the oriental fruit moth include many species that are economically important in controlling numerous other injurious insects. The complex relationships between this host, its parasites and hyperparasites, and the associated hosts of these parasites are rather extensive, although they tend to be concentrated among other small Lepidoptera that live as fruitworms, stem borers, casebearers, leaf rollers, leaf miners, or webworms or whose larvae live in a protected environment. In this publication these relationships are reviewed briefly, available biological information is abstracted, and alternate hosts are listed except for a few extensively polyphagous species.

A major part of this publication is devoted to a discussion of individual parasite species. For each species, the available published information on distribution, hosts, biology, and its parasitism of the oriental fruit moth has been reviewed, and the information gained from the studies at Moorestown has been added.

METHODS OF STUDY

It is unfortunate that many published records of host-parasite relationships are erroneous because of misidentifications or incorrect associations with hosts. In the research at the Moorestown, N.J., laboratory, all specimens representing new records for the species or new locality records for common parasites were identified by specialists at the U.S. National Museum.

The correctness of the association with a host depends on laboratory technique. One of the most com-

[1] Retired 1958.

mon sources of error is the assumption that when a parasite is reared from a lot containing a certain host, which is being reared from plant tissue, that the parasite has issued from that host. In mass rearings it is usually possible that the parasite may have issued from other hosts accidentally included. At Moorestown each lot collected was reared in a screened container until the feeding insects had cocooned. These cocoons were then isolated, one to each 2-dram vial. After emergence the parasites were identified. Whenever there was any doubt as to the host, the host cocoon was opened and its larval remains were carefully examined. They were relaxed in a hot solution of sodium hydroxide, and the anal plate, which is highly characteristic in the oriental fruit moth, was examined microscopically. This process, when referred to in later discussions, is called identification from host remains.

In one method used to study parasitism of oriental fruit moth cocoons, trap bands of burlap or corrugated paper were wrapped around the trunks and large branches of peach trees. After being exposed from one to several weeks, they were removed, and the cocoons were cut out and isolated, one to a vial, for rearing. This method was used in 1931 and 1932. For most of the material reared, the host remains in the tube with each emerged parasite were carefully examined— (1) to prove whether the host was the oriental fruit moth, (2) to observe whether the parasite issued from the prepupa or pupa of this host, and (3) to determine whether the parasite issued directly from the oriental fruit moth as a primary parasite or as a secondary parasite from some of its numerous primary parasites. Since most of the secondary parasites issued from cocoons of primary larval parasites found within the oriental fruit moth cocoons, their status was readily determined.

In the other method employed from 1931 to 1936 and intermittently thereafter, unparasitized oriental fruit moths reared in the laboratory were allowed to cocoon in paper strips. Single cocoons were cut from these strips and pinned to trees for exposure to parasite attack. Usually one freshly formed cocoon was pinned on the shady side of each tree trunk. Each lot contained cocoons exposed on 25 trees randomly distributed in an orchard. In some lots more than one cocoon per tree was exposed, and the lot contained 50 or more cocoons. The cocoons were exposed shortly after being formed and usually were removed before parasite emergence commenced. Most lots were exposed for 4 to 7 days, after which they were removed, and each cocoon was isolated in a small glass vial and reared to completion of emergence.

All quantitative measurements of cocoon parasitism have deficiencies. This is particularly true when the exposure period on trees is short and the cocoons are removed before they have had the normal exposure to parasite attack. Except in late summer, when most of the oriental fruit moths in cocoons are in the overwintering diapause, long exposures on trees are also undesirable, because parasite emergence occurs before the cocoons are removed and some of these parasites cannot be reliably identified from remains in the host cocoon. When there is a heavy mortality among the cocoons without superficial evidence of parasitism, it is difficult to decide whether estimates of parasitism should include or exclude such material. For species always issuing from prepupae, estimates

should usually include dead pupae in the same status as emerged moths. However, among the parasites of oriental fruit moth cocoons there are not many species that always issue from the prepupae.

The method of employing trap bands was better in determining the parasitism of the cocoon, because it permitted natural cocooning in locations selected by the host, and because the cocoons obtained had the normal proportion of the primary larval parasites, which provided reliable data on the true status of the parasites reared. However, this method was often not effective, since there were many orchards where the oriental fruit moth population was so low that few or no cocoons were trapped and the data on parasitism were lacking or meager.

The method of exposing parasite-free cocoons reared in the laboratory provided valuable data on species of parasites attacking the cocoon stage, such as the season when they were prevalent as oriental fruit moth parasites, where they occurred, what stages were attacked, and whether the parasites were really primary parasites of the oriental fruit moth. The relatively high rates of parasitism often obtained in lots of parasite-free cocoons exposed in orchards indicated that when parasitism by primary larval parasites was low or absent, the effect of cocoon parasites would be much more significant. However, the method of exposing laboratory-bred cocoons departed so far from natural conditions that the data obtained had limited value as a quantitative measure of cocoon parasitism.

During the spring and summer of 1957, life-history notes were obtained on several species of cocoon parasites. In the breeding tests, well-ventilated glass tubes, 4 by 1 inch, were placed in frames so that they could not roll. A streak of honey on waxed paper and a small vial containing fresh water provided the adults with food and drinking water. Cocoons of the oriental fruit moth in cardboard corrugations were exposed to ovipositing parasites for 24 hours and were then reared in small isolated lots. In some tests, wooden cages about 24 cubic inches in size, with gauze on two sides, were employed. All rearing was done at nearly optimum temperatures of 80° to 85° F.

SCOPE OF SURVEY

The extent of the survey on which this publication is based is indicated in table 1.

The 25 States from which collections of host and parasite material were received and reared included the following States in which only a small amount of work was done: Rhode Island, Kansas, Mississippi, Louisiana, and Texas. There was some commercial peach growing in nearly all the 265 counties included in the survey, and all the principal peach-growing sections of the Eastern States were represented. Almost a quarter million insects, including both hosts and parasites, were reared in this survey, of which about 92,000 were parasites. The survey of oriental fruit moth larvae infesting peach twigs was much more extensive than that of fruit-infesting larvae or of cocoon parasites.

TABLE 1.—*Numbers of counties, localities, and properties represented by collections of oriental fruit moth larvae and cocoons reared at Moorestown, N.J., 1930–47, and numbers of parasites and total insects reared*

State	Counties	Localities	Properties	Collections	Insects reared	
					Parasites	Total [1]
Arkansas	5	8	14	24	27	796
Connecticut	4	17	29	124	1, 747	5, 033
Delaware	2	6	11	70	3, 377	4, 590
Georgia	19	36	83	142	338	3, 471
Illinois	20	37	75	199	1, 811	6, 072
Indiana	30	44	74	233	2, 504	9, 238
Kansas	3	3	4	8	3	110
Kentucky	12	22	61	154	990	5, 574
Louisiana	3	3	5	10	0	270
Maryland	7	13	28	212	2, 633	7, 679
Massachusetts	8	36	59	145	702	3, 424
Michigan	12	38	55	133	3, 009	5, 604
Mississippi	2	2	2	5	3	252
Missouri	13	16	23	76	557	2, 588
New Jersey	12	48	103	1, 371	44, 665	75, 214
New York	11	58	120	381	5, 496	18, 082
North Carolina	8	15	20	99	184	3, 808
Ohio	31	74	136	511	11, 802	25, 903
Pennsylvania	17	46	91	279	3, 122	8, 882
Rhode Island	3	5	6	6	2	85
South Carolina	15	33	75	219	1, 857	9, 072
Tennessee	1	5	22	107	1, 422	3, 555
Texas	1	1	1	7	0	201
Virginia	21	44	111	440	4, 748	24, 374
West Virginia	5	9	14	34	884	1, 740
Total	265	619	1, 222	4, 989	91, 883	225, 617

[1] Oriental fruit moths and parasites.

PARASITISM AS DETERMINED FROM TRAPPED COCOONS

In 1931, 67 collections of oriental fruit moth cocoons were obtained from 12 counties in 4 States by means of trap bands, from which 1,076 cocoons were reared to emergence. Since they were trapped principally during the first two generations of the oriental fruit moth, they were heavily parasitized by the primary larval parasites of the genera *Macrocentrus*, *Glypta*, and *Pristomerus*. In addition, seven species of cocoon parasites were reared, of which some were secondary parasites. However, during 1931 complete data were not obtained on the host status of all parasites reared.

More extensive collections of trapped cocoons of the oriental fruit moth were obtained in 1932 from 23 counties in 10 States. A total of 2,535 cocoons from 86 collections were reared to emergence. The results are presented in table 2. They provided the best data obtained in any year of the study on the parasitism of the oriental fruit moth cocoons.

TABLE 2.—*Parasitization of oriental fruit moth cocoons collected by means of trap bands, 1932*

State and county	Collections	Host cocoons	Parasitization by—		
			Primary larval parasites	Primary cocoon parasites	Secondary cocoon parasites
	Number	*Number*	*Percent*	*Percent*	*Percent*
Massachusetts:					
Hampden	5	110	11. 2	25. 2	4. 6
Connecticut:					
Hartford	3	104	14. 3	6. 4	5. 7
Tolland	1	44	25. 0	13. 6	11. 4
New York:					
Niagara	6	179	32. 2	2. 1	20. 2
Orleans	3	29	26. 7	10. 3	19. 8
Rockland	3	38	10. 1	21. 6	4. 2
New Jersey:					
Burlington	18	1, 395	12. 5	6. 3	. 5
Pennsylvania:					
Franklin	7	57	6. 5	8. 0	0
Lancaster	2	11	35. 4	6. 2	18. 8
York	5	42	20. 6	2. 5	5. 0
Delaware:					
Kent	1	32	0	0	0
Maryland:					
Washington	8	64	39. 8	8. 1	6. 2
Virginia:					
Augusta	3	24	7. 4	0	3. 7
Botetourt	2	50	7. 3	22. 9	1. 1
Frederick	2	14	73. 1	0	57. 7
Roanoke	1	11	9. 1	18. 2	0
Rockingham	2	28	16. 6	2. 4	4. 8
Kentucky:					
Henderson	1	11	9. 1	9. 1	0
Ohio:					
Erie	2	88	74. 6	3. 0	23. 0
Lake	2	27	78. 6	12. 3	12. 3
Lorain	3	56	6. 9	3. 1	1. 3
Ottawa	3	75	18. 6	2. 3	11. 0
Summit	3	46	38. 4	6. 1	2. 4
Total or average	86	2, 535	25. 0	8. 2	9. 3

Any data on parasitism of oriental fruit moth cocoons that fail to evaluate the role of the secondary parasites can be highly misleading, as illustrated by the results obtained in Erie County, Ohio. Parasitization by primary larval, primary cocoon, and secondary cocoon parasites averaged 74.6, 3.0, and 23.0 percent, respectively. If the data had been based merely on the parasites that issued without determining whether they were primary or secondary, in a total parasitization of 77.6 percent, 51.6 percent would have been credited to larval parasites and 26.0 percent to cocoon parasites. But in this instance most of the cocoon parasites were secondary issuing from the primary larval parasites. It is obvious that these should be added to the total of primary larval parasites and deducted from the total of cocoon parasites. Thus, only 3.0 percent could be credited to cocoon para-

sites, or only about one-twenty-fifth of the 74.6 percent destroyed by primary larval parasites.

The average parasitization by primary larval, primary cocoon, and secondary cocoon parasites (table 2) varied widely from county to county. In more than half of the counties parasitization by primary larval parasites exceeded that by primary cocoon parasites, and the average was three times as great. In nine counties parasitization by secondary cocoon parasites exceeded that by primary cocoon parasites, and the average was slightly greater.

In 1932 a third of the collections were obtained during the first two generations of the oriental fruit moth, when parasitization by larval parasites is relatively high. The combined parasitization by larval and cocoon parasites in these collections was 32.9 percent, of which only 3.5 percent was due to primary cocoon parasites. In the collections made during the third and later generations, which are generally not heavily attacked by larval parasites, primary cocoon parasites destroyed 10.5 percent in a combined parasitization of 29.1 percent. It is concluded that in 1932 cocoon parasites contributed a relatively small portion of the total parasitization, but this contribution was distinctly greater in the third and later generations.

SPECIES THAT ATTACK EGGS OR LARVAE

In the Eastern United States more than 90 species of parasites have been reared that attack the eggs or larvae of the oriental fruit moth. None of these have been reared as hyperparasites, and very few are extensively polyphagous. Most species are diurnal, but *Macrocentrus ancylivorus* Rohwer and probably other species of *Macrocentrus* are crepuscular or even nocturnal.

Trichogramma minutum Riley is the only true egg parasite. The braconids *Ascogaster quadridentata* Wesmael and *Phanerotoma fasciata* Provancher, which attack the eggs but issue from the cocooned larvae, are usually listed with the larval parasites. So far as is known the species of *Perilampus* associated with the oriental fruit moth complex are always hyperparasites. Their larvae enter the larvae of the oriental fruit moth but only develop to maturity when they find there the larvae of some suitable primary parasite. Species of *Bracon* are exceptional among the larval parasites of the oriental fruit moth in their habit of paralyzing the hosts, upon which their larvae feed as ectoparasites. The ichneumonid parasites of the genera *Atrometus* and *Labrorychus* are unusual in their habit of attacking larvae and issuing from pupae.

There is much uniformity in habit among the other parasites that attack oriental fruit moth larvae. Usually the larvae are young when attacked and the eggs are laid internally without paralyzing the host, which does not succumb until after it has cocooned. Usually only one parasite issues from each host, and it pupates within the host cocoon beside its remains. All except the Tachinidae form cocoons that have generic variations in color, form, texture, and type of exit of emerging adults. The sexes are usually nearly equal in number, but in *Agathis diversa* (Muesebeck) males occur only rarely and are probably nonfunctional.

The 11 species of larval parasites that have been most effective against the oriental fruit moth larvae are shown in table 3. There are numerous ways of making quantitative estimates of parasite effectiveness, none of which are entirely satisfactory. For instance, when a large area is being studied, it does not seem desirable to include in the totals used in computing percent parasitization the results of rearing from one or more States where the parasite does not occur with other totals from a State where it is a valuable parasite. Consequently, in this table the percent parasitized is based on total insects reared from collections where the parasite was present. The number of counties in which a parasite occurred is a measure of the broad distribution, and the number of localities and properties is a measure of the completeness of penetration to the limits of the possible environment, which in this instance is assumed to be the orchards infested by the oriental fruit moth. The number of collections from which a parasite has been reared in relation to the number of properties is to some extent a measure of the breadth of seasonal distribution.

M. ancylivorus was in every respect the dominant species, and the large number of localities and properties from which it was reared indicates a relatively high degree of penetration of the possible environment. It was also the only species that conspicuously increased its effectiveness during the period surveyed. The ratio of nearly 4 to 1 of collections to properties also shows a satisfactory seasonal distribution. However, even this valuable and dominant species was recovered from only about two-thirds of the counties and a somewhat smaller fraction of the localities and properties.

Because of its limited distribution *Temelucha grapholithae* (Cushman) is far down on this list, but in districts where it occurred it produced a higher average parasitization than all but three of the species reared. In contrast, *A. quadridentata* has a better distribution than two other species, but it is placed at the bottom, because the average parasitization is less than that of the other species.

The data on which this table was based were obtained principally from the oriental fruit moths that infested peach twigs. If the survey had been based on those infesting apples in unsprayed orchards, it is probable that *A. quadridentata* would have been much higher on the list.

TABLE 3.—*Data on relative abundance of the economically important larval parasites of the oriental fruit moth larvae in the Eastern United States, 1930–47*

Parasite species	Abundance based on collections from which designated parasites were reared								Hosts and parasites reared	Parasitization of oriental fruit moth larvae	
	Counties		Localities		Properties		Collections				
	Number	*Percent*	*Number*	*Percent*	*Number*	*Percent*	*Number*	*Percent*	*Number*	*Number*	*Percent*
Macrocentrus ancylivorus	171	65	375	61	709	58	2, 642	53	144, 679	62, 137	42. 9
Glypta rufiscutellaris	144	54	333	54	548	45	1, 246	26	84, 430	10, 501	12. 4
Macrocentrus delicatus	159	60	275	44	425	35	981	20	52, 451	6, 892	13. 1
Pristomerus euryptychiae	102	38	193	31	271	22	591	12	44, 224	1, 803	4. 1
Temelucha minor	84	32	178	29	279	23	465	9	30, 306	1, 757	5. 8
Macrocentrus instabilis	91	34	161	26	218	18	337	7	25, 475	902	3. 5
Eubadizon pleurale	89	34	132	21	181	15	264	5	17, 788	739	4. 2
Temelucha forbesi	45	17	87	14	112	9	192	4	20, 753	581	2. 8
Temelucha grapholithae	19	7	31	5	41	3	68	1	6, 550	679	10. 4
Horogenes obliteratus	64	24	97	16	124	10	175	4	13, 292	302	2. 3
Ascogaster quadridentata	48	18	84	14	109	9	146	3	14, 483	273	1. 9
Total rearings	265		619		1, 222		4, 989		225, 617	[1] 91, 883	40. 7

[1] Parasitized by all species.

Tachinidae

Six species of Tachinidae are known to be parasitic on the oriental fruit moth in the United States. None are economically important as parasites. The following key to *Lixophaga* adults has been adapted from Aldrich (*1925*),[2] and the key to puparia has been adapted from Greene (*1922*).

Genus LIXOPHAGA

Three species of *Lixophaga* have been recorded as parasites of the oriental fruit moth. Although they are fairly common, almost no biological information on them has been obtained.

The best known member of the genus is *Lixophaga diatraeae* (Townsend), an important parasite of *Diatraea saccharalis* (Fabricius). This parasite is larviparous (Box *1933*). The eggs hatch in the body of the female 6 to 7 days after mating. The larvae are deposited near the entrance to the *D. saccharalis* tunnel, into which they crawl to find the host. The life cycle in Antigua, British West Indies, is 20 to 33 days, and there are 13 generations annually. *L. diatraeae* was readily propagated by dissecting females 7 to 10 days after mating and transferring the larvae to *D. saccharalis* larvae. The other *Lixophaga* species may have a similar life history.

Lixophaga variabilis (Coquillett)

Lixophaga variabilis has been reported by various authors as occurring from Maine to Georgia, westward to South Dakota, Iowa, Missouri, and Texas and in California and Cuba. Aldrich (*1925*) included as hosts three olethreutids

[2] The year in italics after the author's name is the key to the reference in Literature Cited, p. 121.

KEY TO SPECIES OF TACHINIDAE ATTACKING ORIENTAL FRUIT MOTH LARVAE

1. Puparia 10
   Adults 2
2. Fourth vein present beyond bend 3
   Fourth vein evanescent beyond bend ..... *Dichaetoneura leucoptera* Johns.
3. First posterior cell of wing not petiolate at apex 4
   First posterior cell of wing closed with petiole at its apex ..... *Anachaetopsis tortricis* (Coq.)
4. Eyes not pubescent 5
   Eyes densely pubescent ..... *Nemorilla floralis* (Fall.)
5. Females 8
   Males 6
6. With orbital bristles 7
   Without orbital bristles; abdomen without yellow on its sides ..... *Lixophaga variabilis* (Coq.)
7. Lower part of parafacial as wide as third antennal joint ..... *Lixophaga plumbea* Ald.
   Lower part of parafacial much narrower than third antennal joint ..... *Lixophaga mediocris* Ald.
8. Parafacial in lower part much narrower than third antennal joint 9
   Parafacial at narrowest wider than third antennal joint ..... *Lixophaga plumbea* Ald.
9. Third abdominal segment when viewed from behind with broad median black stripe ..... *Lixophaga mediocris* Ald.
   Third abdominal segment with narrow partial stripe or none; abdomen without coarse dots, sides not yellow ..... *Lixophaga variabilis* (Coq.)
10. Spiracles at most only moderately protruding 11
    Spiracles strongly protuberant and divergent from base, cleft between them V-shaped; spiracular plate with five slits ..... *Anachaetopsis tortricis* (Coq.)
11. When viewed from side, spiracles on or below longitudinal axis ..... *Dichaetoneura leucoptera* Johns., *Lixophaga variabilis* (Coq.)
    When viewed from side, spiracles distinctly above longitudinal axis ..... *Nemorilla floralis* (Fall.)

and three species of Coleoptera, representing three families, all of which are borers. Thompson (*1951*) listed 11 hosts, all of which are Lepidoptera and most of them stem borers, including five olethreutids, three pyraustids, and two phalaenids. Satterthwait and Swain (*1946*) and Satterthwait (*1948*) recorded that *variabilis* was parasitic on several species of Lepidoptera infesting the seed heads or stems of sunflower (*Helianthus*). Thus *variabilis* is primarily a parasite of lepidopterous larvae that tunnel in stems, fruits, or nuts. It is especially a parasite of Olethreutidae.

Little information has been published on the biology of this species, except that it is a parasite of larvae. Satterthwait and Swain (*1946*) found that in the sunflower budworm *Suleima helianthana* (Riley) the mature parasite larva issued from the host larva to form its puparium. Satterthwait (*1948*) observed that in Missouri the life cycle required at least 21 days, that there were several generations a year, and that the parasite overwintered as a puparium.

L. variabilis was first recorded from the oriental fruit moth by Garman (*1918*) in Maryland and Wood and Selkregg (*1918*) in Virginia in 1918. It has since been recorded from that host by various workers in New Jersey, Delaware, Maryland, Virginia, Georgia, Ohio, and Missouri (Stearns *1919*, *1928*, Snapp and Swingle *1929*, Haeussler *1930*, Stearns and Neiswander *1930*, McConnell *1932*, Stearns and Amos *1941*, Wingo *1941*, Bobb *1942*).

At the Moorestown laboratory *variabilis* was reared as a parasite of the oriental fruit moth from 72 collections of infested peach twigs obtained from 63 properties, 53 localities, and 41 counties, which were, respectively, 1.4, 5, 9, and 15 percent of the total surveyed. In several collections the rate of parasitization by *variabilis* was slightly over 5 percent. In the collections from which it was recovered, parasitization by *variabilis* was 1.9 percent of the 4,928 total insects reared. It was an uncommon parasite in the northern part of the peach-growing area. It was not recovered from Michigan and was rare in Ohio, New York, and Connecticut—all States where many collections were made. It was most abundant as a parasite of the oriental fruit moth in Illinois, Missouri, Kentucky, and South Carolina.

At the Moorestown laboratory *variabilis* attacked the larvae of the oriental fruit moth. In one host a respiratory funnel was found in the fourth abdominal segment. The mature larvae issued from host prepupae and formed their puparia in the cocoon beside the remains of the host.

L. variabilis occurred commonly in southern New Jersey in several alternate hosts abundant near peach orchards. It was reared from both the summer and the overwintering generation of *Epiblema strenuana* (Walker) and from the overwintering generation of *E. scudderiana* (Clemens), *Rhyacionia rigidana* (Fernald), and a borer of *Bidens*, probably *E. otiosana* (Clemens).

Lixophaga mediocris Aldrich

Lixophaga mediocris has been reported from Virginia, New Jersey, Ohio, and Tennessee (Aldrich *1925*, Driggers *1929*, Butler *1932*). It appears to be a fairly common parasite of *Rhyacionia frustrana* (Comstock) larvae in Virginia (Cushman *1927*, Underhill *1943*). Cushman stated that it forms a puparium in the host burrow. *L. mediocris* has been recorded as a parasite of the oriental fruit moth in New Jersey (Driggers *1929*), Ohio (Stearns and Neiswander *1930*), and Tennessee (Butler *1932*, *1933*).

At the Moorestown laboratory

mediocris was reared from collections of the oriental fruit moth infesting peach twigs from Virginia, South Carolina, Kentucky, Tennessee, Ohio, Indiana, and Illinois. It was reared from 24 collections, 22 properties, 19 localities, and 15 counties, which were, respectively, 0.5, 1.8, 3, and 6 percent of the total surveyed. This parasite attacked the larval stage. At least during the second instar, the parasite larva was footed in a respiratory funnel attached near the first abdominal spiracle. The parasite usually issued from oriental fruit moth prepupae and formed its puparium beside the host remains. One specimen was reared in 1932 from *Rhyacionia rigidana* collected at Medford, N.J.

Lixophaga plumbea Aldrich

The distribution of *Lixophaga plumbea*, as reported by various authors, includes Ontario, New Jersey, Delaware, Maryland, Virginia, Indiana, and South Dakota. This species has been recorded (Aldrich *1925*, Cushman *1927*, Underhill *1943*) from only two hosts other than the oriental fruit moth. It is a fairly common parasite of *Rhyacionia frustrana* and has been reared from *Phalonia oenotherana* Riley. Cushman stated that it was an internal parasite of *R. frustrana* larvae. It was reared from the oriental fruit moth in New Jersey (Aldrich *1925*, Driggers *1929*, Haeussler *1930*), Ontario (Steenburgh *1931*), and Delaware (Stearns and Amos *1941*).

At the Moorestown laboratory *plumbea* was reared from collections of infested peach twigs from Connecticut, New York, New Jersey, Ohio, and Indiana. It was reared from 11 collections, 10 properties, 10 localities, and 8 counties, which were, respectively, 0.2, 0.8, 1.7, and 3 percent of the total surveyed.

Nemorilla floralis (Fallén)

Nemorilla floralis has been reported in voluminous literature under several names. It is a common parasite of Lepidoptera in Europe and North America. Clark (*1934*) also found it in Japan. Aldrich and Webber (*1924*) recorded it as occurring from New England to Idaho and Arizona and in Canada, Cuba, and the Virgin Islands.

N. floralis is parasitic on many of the smaller species of Lepidoptera. Thompson (*1951*) listed 30 hosts, of which more than half are pyralids or tortricids. Shaffner and Griswold (*1934*) in very extensive rearing work in New England did not find it parasitic on a single species of Macrolepidoptera. It belongs to the well-known group of Tachinidae, which lay macrotype eggs on the host.

Comparatively little has been published on the biology of this species. Clark (*1934*) reared it from overwintering larvae of *Pyrausta nubilalis* (Hübner). Nickels et al. (*1950*) found that in Texas it attacked the overwintering larvae of *Acrobasis caryae* Grote. The egg was usually deposited on the head or thorax. Generally the puparium was found within the host pupa.

It has been reported as a parasite of the oriental fruit moth in Ontario, New Jersey, and Maryland (Garman *1918*, Stearns *1928*, Haeussler *1930*, Steenburgh *1931*, McConnell *1932*, Brunson and Allen *1948*). *N. floralis* is only rarely a parasite of the oriental fruit moth in the Eastern United States.

At the Moorestown laboratory only three individuals were reared from the many thousands of larvae collected. These were from Sodus, N.Y., East Longmeadow, Mass., and Cinnaminson, N.J.

Anachaetopsis tortricis (Coquillett)

The distribution of *Anachaetopsis tortricis*, as reported by various

authors, includes Ontario, New Jersey, Pennsylvania, Delaware, Indiana, Missouri, Washington, Oregon, and California.

There are 12 recorded hosts, all Lepidoptera whose larvae spend most of their lives as casebearers or concealed under webs, or in folded leaves, seed heads, fruit, nuts, or stems. Four of the hosts are olethreutids, two gelechiids, two tortricids, and there is one each in the families Coleophoridae, Phycitidae, Psychidae, and Pyraustidae. Among the recorded hosts commonly found near peach are *Carpocapsa pomonella* (Linnaeus), *Anarsia lineatella* Zeller, and *Ancylis comptana fragariae* (Walsh & Riley). *A. tortricis* has been reported as a parasite of the oriental fruit moth in Ontario (Van Steenburgh *1935*) and Missouri (Wingo *1941*).

Scattered notes on the biology of this species have been published. Shaffner and Griswold (*1934*) found that in the Northeastern States there were at least two generations a year in *Thyridopteryx ephemeraeformis* (Haworth) and only one individual issued from each host. Dohanian (*1942*) observed that in Washington and Oregon it normally overwintered in the larvae of *Melissopus latiferreanus* (Walsingham) and emerged from the pupae. Beacher (*1947*) found that it parasitized the overwintering generation of *Coleophora malivorella* Riley and issued from the pupae. Satterthwait and Swain (*1946*) dissected gravid females and found that mature eggs had one flat and one strongly convex surface. Apparently this species is not larviparous. In *Homoeosoma electellum* (Hulst) they observed that the prominent, diverging spiracles of the maturing larva protruded beneath the wing pads of the host pupa. After the pupa was killed, puparia were formed within the host pupal case.

At the Moorestown laboratory *tortricis* was reared from the oriental fruit moth in peach twigs collected in New York, Maryland, Virginia, Ohio, Indiana, Illinois, and Missouri. Not one was reared from over 75,000 oriental fruit moths collected in New Jersey peach orchards. Sixty-seven percent of the 64 individuals reared issued from collections made in Ohio and Indiana. Parasitization by *tortricis* in the latter was over 5 percent in several collections, and in one collection 10 percent of the 87 insects reared were this species. It was reared from 36 collections, 34 properties, 27 localities, and 26 counties, which were, respectively, 0.7, 2.8, 4, and 10 percent of the total surveyed.

Dichaetoneura leucoptera Johnson

Dichaetoneura leucoptera is one of a small group of tachinids in which the apical cell is not closed or narrowed at its apex. Published records indicate a distribution in Nova Scotia, Ontario, the New England States, and New York. In places it occurs as the dominant parasite of *Archips cerasivoranus* (Fitch). Johnson (*1916*) reared 104 from six webs taken at Bennington, Vt., but Hoffman (*1936*) did not recover one from several hundred of this host reared at St. Paul, Minn., in 1932. Baird (*1918*) noted that the larvae of *A. cerasivoranus* were parasitized in July and the parasite became full grown in about 3 weeks. He stated that the tachinid issued from the larvae, which might live for some time thereafter, and that the puparia were found in the nests of the host or in the trash on the ground. Adults from this generation emerged the same season and were long lived.

Leonard (*1920*) found that in *Depressaria heracliana* (Linnaeus) the larva issued from the host pupa.

Thompson (*1953a*) found that in *A. cerasivoranus* all larvae issued from the host pupae and that they all had an opening of an integumentary funnel on the ventral aspect of the last segment. Cast skins of first-instar larvae embedded in the funnel of mature larvae indicated that this position had been established early in the larval period. The youngest first-instar larvae found were of the "planidium" type, which are usually ready to hatch as soon as the eggs are laid. Thompson (*1953b*) stated that when an associate and he were working with larvae of *D. heracliana* and of *A. cerasivoranus*, respectively, they found that in both species first-instar larvae were located in the hindgut, a habit nearly unique in tachinids. By sectioning the specimens Thompson showed that the larvae were established in a pouch between the chitinous intima and the epithelium of the gut, and apparently they pushed their funnels through the cuticle from this location. According to Thompson, the only host known, except those named, is *Epiblema strenuana*.

At the Moorestown laboratory only one specimen was reared from the oriental fruit moth. This was obtained from larvae collected in infested peach twigs taken on June 5, 1936, at Smithsburg, Md. The host was positively identified from an examination of its remains, and the adult was identified by D. G. Hall at the U.S. National Museum. It emerged from a puparium formed within the host pupa.

Braconidae

The Braconidae, a family of Hymenoptera, includes several of the most effective parasites of the oriental fruit moth, as well as numerous other species of varying abundance. Insofar as is known braconids attack the oriental fruit moth only as parasites of developing larvae. In the Braconidae the third discoidal (fig. 2, *A*) and second apical cells of the forewing are confluent. The first cubital and first discoidal cells are usually separate. There is no articulation between the second and third abdominal segments.

KEY TO GENERA OF BRACONIDAE ATTACKING ORIENTAL FRUIT MOTH LARVAE

1. Abdomen with more than three visible tergites 3
   Abdomen ovate, with smoothly rounded apex and sides; not more than three visible tergites 2
2. Yellow; abdomen with three visible tergites ..... *Phanerotoma*
   Black; abdomen with one visible tergite ..... *Ascogaster*
3. Abdomen not petiolate 4
   Abdomen petiolate ..... *Meteorus*
4. First cubital and first discoidal cells separated 5
   First cubital and first discoidal cells confluent; radius close to and parallel to posterior apical margin of stigma ..... *Agathis*
5. Usually more than 4 mm. long; terminal abscissa of radius well developed; abdomen longer or larger than thorax 7
   Usually less than 4 mm. long; blackish; terminal abscissa of radius absent or represented by short spur or translucent fold; abdomen usually distinctly smaller and shorter than thorax 6
6. Areolet present, although small and indistinctly closed at apex ..... *Microgaster*
   Areolet absent ..... *Apanteles*
7. Abdomen much more than twice as long as greatest width 8
   Abdomen at most not much more than twice as long as greatest width ..... *Bracon*
8. With only one cubital cell ..... *Eubadizon*
   With two cubital cells ..... *Macrocentrus*

Meteorus trachynotus Viereck

(Fig. 1)

Meteorus trachynotus has become well known as a widely distributed and valuable North American parasite of *Choristoneura fumiferana* (Clemens), in which its parasitism has been studied by several workers, including Dowden et al. (*1950*) and McGugan (*1955*). Some workers have noted that *trachynotus* attacks fourth-instar larvae of this host and that it is more effective in a declining than in a rising infestation. After the parasite issues, *C. fumiferana* larvae survive for several days but fail to pupate. The overwintering host has not been found.

Muesebeck et al. (*1951*) stated that *trachynotus* occurs from Massachusetts to Florida, from British Columbia to California, and in Canada, Utah, and Louisiana. In addition to *C. fumiferana*, it is a primary parasite of several leaf rollers and budworms of the families Tortricidae and Olethreutidae, including some common pests.

M. trachynotus was reared as an occasional parasite of the oriental fruit moth by Stearns and Neiswander (*1930*) in Ohio, Daniel (*1932*) in New York, Merritt (*1933b*) in Michigan, and Stearns and Amos (*1941*) in Delaware.

At the Moorestown laboratory four specimens—one each from Ringgold, Md., and Vermilion, Ohio, and two from Columbus, Ohio—were reared from oriental fruit moth larvae infesting peach twigs. The host relationship was proved for two of the reared specimens by examining the larval remains. In one specimen the parasite issued from the cocooned host prepupa and formed a small white cocoon.

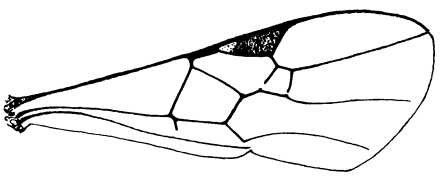

FIGURE 1.—Forewing of *Meteorus trachynotus*.

Genus MACROCENTRUS

The genus *Macrocentrus* includes four species parasitic on the oriental fruit moth in the Eastern United States. One is the dominant larval parasite in much of this area; another is frequently a dominant parasite for part of the season, particularly in midsummer; a third is occasionally abundant; and the fourth has been reared infrequently. The adults are delicate, slender insects, largely ferruginous to pale yellow, and about the size and shape of mosquitoes. The *Macrocentrus* species can be distinguished from the somewhat similar *Eubadizon pleurale* Cresson by the presence of two cubital cells on the wings (figs. 2 and 4, *A*).

Insofar as is known the biology of the *Macrocentrus* species is similar. However, they differ in the species of hosts attacked. They are exclusively primary parasites of small Lepidoptera, attacking very small to half-grown larvae. Their common alternate hosts include fruitworms, stem borers, and leaf rollers found in crops and weeds near peach orchards. They issue from the larvae after they have cocooned and form parchment-textured ovoid cocoons, which are usually dark brown, beside the host remains. Only one parasite issues from each host. Usually the life cycle is well adjusted to that of the host, which may have a variable number of annual generations. The *Macrocentrus* species overwinter as first-instar larvae in hibernating host larvae.

KEY TO SPECIES OF MACROCENTRUS ATTACKING ORIENTAL FRUIT MOTH LARVAE

(Fig. 2)

1. First abdominal tergite appreciably depressed or excavated at base; spiracles of first tergite nearer base than to each other; stigma usually more or less brownish or infuscated 2
   First abdominal tergite not depressed or excavated at base; spiracles of first tergite farther from base than from each other; stigma always uniformly pale yellow ..... *delicatus* Cress.
2. Length of first discoidal cell distinctly greater than that of first cubital cell; stigma variable; palpi yellow or testaceous but not infuscated; nervulus postfurcal at least nearly its own length 3
   Length of first discoidal cell at most slightly greater than that of first cubital cell; stigma brown and concolorous; palpi infuscated; nervulus postfurcal at less than half its length ..... *pallisteri* DeGant
3. Nervulus postfurcal by distinctly less than its own length; stigma never concolorous, fuscous apically, pale at base; palpi testaceous ..... *ancylivorus* Roh.
   Nervulus postfurcal by about its own length; stigma usually concolorous, brown; palpi pale yellow ..... *instabilis* Mues.

Macrocentrus ancylivorus Rohwer

(Figs. 2 and 3)

Macrocentrus ancylivorus was described in 1923 (Rohwer *1923*) after it had been discovered to be a valuable parasite of *Ancylis comptana fragariae* in New Jersey. By 1926 it was known to be a common parasite of the oriental fruit moth in southern Connecticut, southern New Jersey, and eastern Pennsylvania. Shortly thereafter it was noted as a parasite of this host in several peach-growing sections along the Coastal Plain from Connecticut to Virginia. Several authors assumed that a *Macrocentrus* species described in the early records as reared from the oriental fruit moth was *ancylivorus*. However, the early survey work at the Moorestown laboratory indicates that this *Macrocentrus* species could have been *M. delicatus* or *M. instabilis*.

Muesebeck (*1932*) in his revision of the genus in 1932 found that *ancylivorus* was distributed far beyond the area then known to be infested by the oriental fruit moth, and he identified specimens taken as early as 1910. Careful search in all areas of the world outside North America infested by the oriental fruit moth has failed to uncover any species closely resembling *ancylivorus*. In 1942 (Dohanian *1942*) it was recorded as a common parasite of *Melissopus latiferreanus* in acorns in western Oregon and in California, well removed from any known infestations of the oriental fruit moth. Thus the available evidence indicates that this species is North American and that it has long been distributed transcontinentally and from Massachusetts south to Texas.

Its life history was described in detail by several authors, notably Fink (*1926*), Haeussler (*1932*), and Daniel (*1932*). It is somewhat similar to that of numerous other Hymenoptera that attack the twig-infesting larvae of the oriental fruit moth. Adults mate soon after emerging. They have a short preovipositional period of about 2 days and a short life span averaging less than 2 weeks in midsummer. Daniel found that when well-fed adults were maintained at 80° F., the females lived on an average for 12.5 days and the males for 10.7 days.

Haeussler observed that *ancylivorus* attacked very young to nearly mature larvae. In the field he found them parasitizing oriental fruit moth larvae during the day and night.

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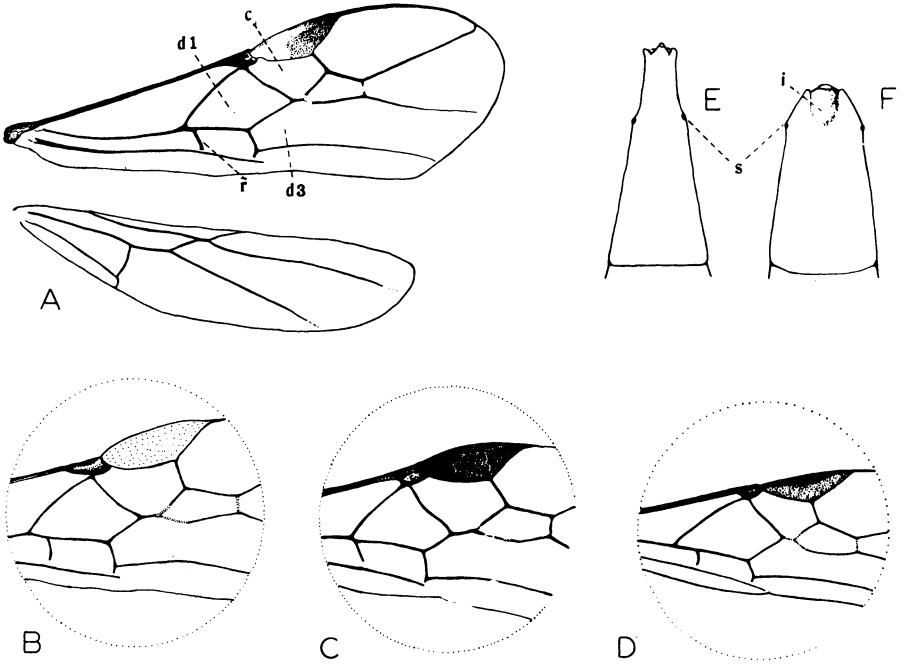

FIGURE 2.—*A*, Wings of *Macrocentrus ancylivorus*, showing first discoidal cell (*d* 1), third discoidal cell (*d* 3), first cubital cell (*c*), and recurrent vein (*r*). *B*, Section of forewing of *M. delicatus*. *C*, Section of forewing of *M. pallisteri*. *D*, Section of forewing of *M. instabilis*. *E*, First tergite of *M. delicatus*. *F*, First tergite of *M. ancylivorus*, showing impressed area (*i*) and spiracle (*s*).

Several workers observed that ovipositing females were stimulated by the frass of the host. Daniel stated that the newly deposited egg (fig. 3, *A*) was only 0.08 mm. long and elliptical and had a round, slender anterior end. The egg containing the embryo and ready to hatch (fig. 3, *B*) was spherical and much larger. The first-instar larva has a flattened, heavily-sclerotized head and three prominent curved processes on the anal segment (fig. 3, *C*). He observed four larval instars. The larva develops at a rate determined by that of the host and matures when it cocoons, issuing and forming a cocoon within that of the host. The cocoon is closely woven, shining, and usually mahogany brown. It has nearly parallel sides and rounded ends, forming a rather elongated ovoid. Emergence occurs through a circular cap severed

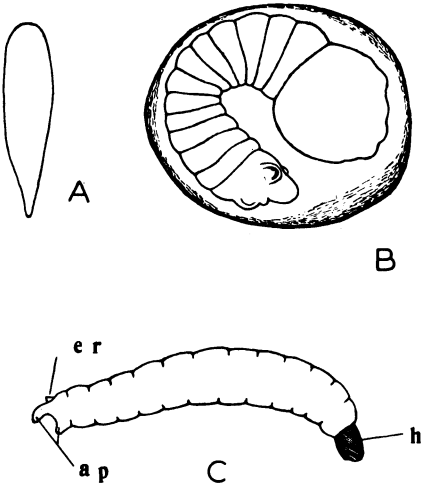

FIGURE 3.—*Macrocentrus ancylivorus*: *A*, Newly laid egg; *B*, egg containing embryo and ready to hatch; *C*, first-instar larva, showing head (*h*), anal process (*a p*), and evaginated rectum (*e r*). (Redrawn from Daniel (*1932*).)

from the anterior end. In the oriental fruit moth at optimum temperatures the period from egg to adult for *ancylivorus* is about 1 month.

Muesebeck et al. (*1951*) and Krombein et al. (*1958*) listed 14 hosts of *ancylivorus*. They are small Lepidoptera whose larvae live in a protected environment, principally as stem borers, fruitworms, or leaf rollers. Seven of these hosts are olethreutids, two gelechiids, two phycitids, and one each in the families Phaloniidae and Tortricidae. Probably the strain or strains that attack some of these hosts are biologically distinct from the strain commonly parasitic on the oriental fruit moth and *A. comptana fragariae*. Several of the hosts are crop pests, but apparently *ancylivorus* is an important parasite only of the two hosts named.

Epiblema strenuana and *A. comptana fragariae* serve as reservoirs of *ancylivorus* near peach orchards. The rate of parasitization of *E. strenuana* by *ancylivorus* is low (Allen and Lott *1930*, Pepper and Driggers *1934*, Haden *1935*, Bobb *1942*). However, the enormous populations of this host in ragweed (*Ambrosia*), which is almost always abundant in and about peach orchards, make *E. strenuana* an important reservoir of this parasite. *A. comptana fragariae* not only infests cultivated strawberry (*Fragaria*), raspberry (*Rubus*), and blackberry (*Rubus*) but maintains large populations in several species of Rosaceae, particularly in wild blackberries and dewberries (*Rubus*). These populations are usually heavily parasitized by *ancylivorus* and serve as an important reservoir of this parasite. They commonly occur near peach orchards (Allen *1945*).

Although some of the *Macrocentrus* parasites first reared from the oriental fruit moth may have been *M. delicatus* or *M. instabilis*, those reared at Washington, D.C., in 1917 (Wood and Selkregg *1918*) and by Garman in the same year at College Park, Md., (Garman *1918*) were probably *ancylivorus*. The first published report of this species in the oriental fruit moth was by Garman (*1926*) in 1925 from Wallingford, Conn. Subsequently there have been hundreds of published reports on its abundance in this host from Massachusetts west to Kansas and south to Georgia.

In 1928 Daniel (*1928*) reported on liberations of *ancylivorus* in orchards in Niagara County, N.Y., and Steenburgh (*1930b*) reported on liberations started in Ontario in 1929. Both obtained parasites from parasitized *A. comptana fragariae* collected in New Jersey. Between 1929 and 1935 Allen et al. (*1940*) at Moorestown, N.J., in cooperation with entomologists of several State agencies carried out an extensive program of releasing this parasite. Numerous recovery records show that this effort was highly successful, and very shortly the parasite was well established in scores of districts where it had not previously occurred as a parasite of the oriental fruit moth. Steenburgh (*1930b*) reported a dispersion, from his initial colonization during the season liberated, over an area of at least 35 square miles. Others observed a similar dispersion.

There have been some differences of opinion on the value of colonizing *ancylivorus*. Many of the claims of benefits have been based on cursory observations. However, there have also been a few detailed studies. Daniel (*1936*) showed that in Niagara County, N.Y., parasitism, due to the introduction of *ancylivorus*, increased steadily from 1928 to 1933, and during the same period injury to peaches decreased from 18,900 injured fruits per acre in 1929 to 4,500 in 1933. Yetter and Allen (*1940*) and Allen (*1943*),

reporting on a 3-year study of 51 orchards in 11 districts, showed that orchards with heavy parasitism, mainly by *ancylivorus*, had less injury than orchards with lower parasitism. Boyce (*1947a*), in summarizing the parasitism of the oriental fruit moth in Ontario from 1929 to 1946, observed that control had greatly improved, because *ancylivorus* was added to the parasite complex and principally because of its increased parasitism during the first generation of the oriental fruit moth.

Efforts to establish *ancylivorus* obtained from Moorestown on the oriental fruit moth in countries outside North America have been reported by Allen and Haeussler (*1932*) for France, Grandi (*1933*) for Italy, Ishii (*1940*) for Japan, Lopez-Cristobal (*1941*) for Argentina, and Helson (*1947*) for Australia. So far as is known to the author no foreign colonization has been permanently successful.

The literature is extensive on the mass production of *ancylivorus*. During the 1930's adult parasites were obtained by methods described by Allen et al. (*1940*) from larvae of *A. comptana fragariae* collected in strawberry fields or from large field breeding cages over strawberry. They were also obtained by exposing to breeding females in ovipositing cages either peach twigs or apple slices infested with small oriental fruit moth larvae (Daniel et al. *1933*, Garman *1933a*). All these methods were laborious, expensive, or failed to produce during the entire season an abundance of parasites suitable for release.

In 1944 Finney et al. (*1944*) reported a remarkably successful method utilizing *Gnorimoschema operculella* (Zeller) as a host. This method made the continuous rearing of unlimited numbers possible and enormously decreased the cost of obtaining supplies of the parasite. The method, with several refinements by other workers, was more fully described in 1947 (Finney et al. *1947*).

Brunson (*1940*) reported that mass liberations of *ancylivorus* in orchards where it already occurred would reduce fruit injury. Allen (*1948*) reported an average reduction of 50 percent in fruit injury after similar liberations in 100 to 140 acres of peach trees each year for 10 years. Brunson and Allen (*1954*) in a control program showed that mass liberations of *ancylivorus* in combination with a reduced number of spray applications were as effective as a larger number of spray applications without the parasites.

Numerous other reports have been made on the economic use of *ancylivorus*. Marvin (*1945*) found that *ancylivorus* originating from *A. comptana fragariae* parasitized oriental fruit moths on peach trees as effectively as those originating from parasitized peach twigs. *M. ancylivorus* tends to produce an undesirable excess of males when it is reared in confinement. Among the numerous articles discussing sex ratios are those of Garman and Schread (*1931*), Holloway (*1934*), Flanders (*1945*), and Martin and Finney (*1946*).

The breeding of vigorous *ancylivorus* parasites from *G. operculella* has been hampered by infections of the protozoan *Nosema destructor* S. & H., which occurs in *G. operculella* and *ancylivorus* reared from it. This nosema disease was first noted by Allen and Brunson (*1945*). McCoy (*1947*) developed a control for it by starting *G. operculella* cultures with disease-free eggs. At the Moorestown laboratory it was more readily controlled by heating the unincubated eggs (Allen and Brunson *1947*, Allen *1945a*).

The effects of the newer organic insecticides on *ancylivorus* have

been studied by Peterson (*1946*), Rings and Weaver (*1948*), Pielou (*1951*), Pielou and Glasser (*1952*), and Allen (*1957*, *1958*). Since mass production of *ancylivorus* is easy and the adult is highly sensitive to small amounts of the new organic insecticides, this parasite has been used in bioassay (Fleming et al. *1951*).

As shown in table 3, *ancylivorus* was by far the most abundant larval parasite of the oriental fruit moth in the Eastern States. In table 4 the yearly abundance of *ancylivorus* is summarized, based on data obtained when the parasite was reared from infested peach twigs collected from 1930 to 1947. The first extensive liberations were made in 1930 and were continued by State or Federal agencies throughout the period of this survey. Data in this table are based on records from 138 counties, representing most sections in the Eastern United States where peaches are produced commercially.

At the beginning of these observations *ancylivorus* was unquestionably the dominant parasite only in the five New Jersey and two Delaware counties surveyed. Before liberations were begun it was absent or present only in limited numbers in the others. In some widely scattered counties such as Niagara, N.Y., Augusta, Va., Ottawa, Ohio, and Knox, Ind., this parasite became dominant from the first year of liberation. In others, several years passed before *ancylivorus* became dominant, and in some counties such as York, S.C., it failed to become established for many years after the first liberation.

In the survey the percent of counties in which *ancylivorus* was dominant increased steadily from 16 in 1930 to 68 in 1940–47. The percent of counties where it was not recovered decreased gradually from 51 in 1930 to 24 in 1940–47. At the conclusion of the survey in the middle 1940's there were still numerous counties in the Mississippi Valley from Ohio to Louisiana where *ancylivorus* was apparently absent as a parasite of the oriental fruit moth, or it was present only in small numbers.

Macrocentrus delicatus Cresson

(Fig. 2)

Macrocentrus delicatus is a North American species. According to Muesebeck et al. (*1951*) and Krombein et al. (*1958*) it occurs from Quebec to Florida and west to Manitoba and Texas. It is moderately polyphagous. The hosts listed by Muesebeck include seven olethreutids and one each of the families Pyraustidae, Gelechiidae, Phycitidae, Epipaschiidae, and Phalaenidae. Poos and Hetrick (*1945*) reared it from *Tetralopha scortealis* (Lederer), another epipaschiid. The hosts are small Lepidoptera that feed in protected locations. They are stem and fruit borers, bud moths, fireworms, and webworms. The species has frequently been confused with others. This is obviously the reason that Muesebeck did not recognize all the published host records or the entire distribution area given in these records.

The life history of this parasite was never studied in detail, but it is certainly similar to that of *Macrocentrus ancylivorus*, with which it is frequently associated. *M. delicatus* attacks the larva. It completes its development when its host has cocooned, issues from the cocooned larva, one to each host, and spins its cocoon within that of the host. It overwinters as a small larva within the hibernating host larva.

M. delicatus has been reared more frequently from the oriental fruit moth than from any indigenous host. It has been reported as a parasite of this host from Ontario

TABLE 4.—*Status of* Macrocentrus ancylivorus *as a larval parasite of the oriental fruit moth as determined at Moorestown, N.J., from infested peach twigs collected in 138 counties, 1930–47* [1]

State and county	1930	1931	1932	1933	1934	1935	1936	1937	1938	1939	1940	1941	1942	1943	1944	1945	1946	1947
Massachusetts:																		
Hampden		P	P	P	P				P									
Hampshire	A		A	P	A													
Middlesex				A	A			A	P									
Plymouth				P	P	A												
Worcester				P	P	P		P	P									
Connecticut:																		
Hartford	P	D	D	D	D			P	D									
Middlesex				P	D			D	D									
New Haven	P			D	D			D	D									
Tolland		P	P	A	A													
New York:																		
Chautauqua	A	A	A															
Monroe			A	D	D	D	A	D	D	D								
Niagara	D	D	D	D		D	D	D	D									
Orange		A	A	A	A	A		A										
Orleans		A	P	P	A	D	D	D	D									
Rockland		A	P	A	A	P	A	A										
Schuyler					D		D	D										
Ulster				P	P	A		P										
Wayne				A		P	A	D	D	D								
New Jersey:																		
Atlantic		D		D	D													
Burlington	D	D	D	D	D	D	D	D	D	D	D	D						
Camden		D	D	D	D	D	D	D			D	D						
Gloucester	D	D		D	D	D	D	D	D		D	D				D		
Mercer		D		D	D	D		D	D	D								
Pennsylvania:																		
Adams		P		A	D	D	D	D	D							D		
Allegheny	A	P	A															
Beaver	A	A	A	A	P													
Erie	A	P	P	P	P		P									D		
Franklin		A	D	P	D	D		D	D									

Juniata				P	P	P													
Lancaster		P	A														D		
Washington			A	A	A														
York		A	D	D	D				D								D		
Delaware:																			
Kent		D			D	D		D											
Sussex			D	D	D	D		D				D							
Maryland:																			
Washington		P	P	D	D	D	P	D	D	D									
Wicomico		D		P	D	D	D	D	D										
Worcester	P	D	D	D	D			D	D										
West Virginia:																			
Berkeley		A							D	D									
Virginia:																			
Albemarle		A	A	P	D	D	D	D	D	D							D		
Amherst						A	A	A	A										
Augusta		D	D	D	D	D	D	P	P	D							D		
Botetourt		A	A			P	A	A	D								D		
Frederick		A	P			P	A	A	P	D									
Loudoun	A	A	A	A					P										
Nelson		A				P	A	D	D	D									
Rappahannock			A	A			P												
Roanoke		P	D		A	A	A	P	D										
Rockingham		A	P	A	P	A	A	P	A	P							D		
North Carolina:																			
Montgomery		A				P	A	A	A										
Moore	P	A	A	A	A	P	A	A	A										
Wake	D	D	A		A	P	A	A											
South Carolina:																			
Anderson		A	A	A	A	P		A									D		
Edgefield									P					D				D	
Greenville	P	P	P	D	D	D	D	P	D					D			D	D	
Laurens	A	A	A	A	A		P	A						D	D			D	
Oconee		P	A		A	P		A	A					A				D	
Pickens			A	A	D	A		A	A										
Saluda					A			A	P					D					
Spartanburg	P	A	A	A	D	D	D		D					D	D		D	D	
Union							A							D			D		
York	A		A		A			A	A					A			A		

See footnote at end of table.

TABLE 4.—*Status of* Macrocentrus ancylivorus *as a larval parasite of the oriental fruit moth as determined at Moorestown, N.J., from infested peach twigs collected in 138 counties, 1930–47* [1]—Continued

State and county	1930	1931	1932	1933	1934	1935	1936	1937	1938	1939	1940	1941	1942	1943	1944	1945	1946	1947
Tennessee:																		
Roane	P	P	A	A	P													
Kentucky:																		
Fayette			A						A							A		
Henderson	P	D					D	D	D				D			D	D	
Kenton	P	A	A					A	A				A			A		
McCracken	P	A						A	P				P			D	D	
Union	A	A						A	P							P	A	
Ohio:																		
Ashtabula		A	A	P	A		D	D										
Belmont		P	P	A	A		A		A	P								
Clermont		P	A					A	A	A								
Columbiana		A	A	A	P			A	A									
Cuyahoga		D	D	D	D		D	D	D									
Erie	A	D	D	D	D	D	D	D	D									
Fairfield		A	P	P	A		A	A	A	A								
Franklin	P	A	A	P				A	A	P								
Hamilton	D	A	A		A	A	A	A	P	P								
Knox		A	A	A	A		A	A	A	A								
Lake	P	D	D	D	D	D	D	D										
Lawrence	A		A	A	A	P	A	A										
Licking					D		A	A	A									
Lorain	A	A	D	A	D	D	D	D	D	D								
Medina								A	P	P								
Montgomery			A		A			A	D	D								
Ottawa	D	D	D	P	D	D	D	D	D									
Ross		A	P	P	A		A		A	A								
Sandusky								D	D	D								
Summit		P	D	D	D	D	D	D	D	D								
Wayne		P	P	A	A	D	P	P	D	P								
Indiana:																		
Brown	A														A		A	
Delaware														A	A		A	
Elkhart					A			P	P	D				D	D			

Floyd	P	A			A	A	A			A					A		A	
Gibson	A					A	P											
Greene					A	A	A	A	D	A								
Harrison				A	A	A	A			A								
Howard														A	P	A		
Jackson					A		A			A								
Jefferson								A	A	A								
Johnson					A			A	A	A				A				
Knox	D	D	D		D	D	D	D	D	D								
Lawrence		A				A	P	A	A	A					A		A	
Martin	A				A	P	A	P	A	A								
Morgan		A			A		A	A	A	A				A	P		D	
Orange	A	A					A			A								
Owen					A	A	A											
Pike								A	A	A					A		P	
Posey	A			A	A	A	A	A	A	A								
Warrick	A			A		A	A								P			
Washington					A		A			A								
Michigan:																		
Berrien				P	D	D	D	D	D	D								
Macomb								A	A	P								
Oakland				A	A	P	P	A	A	P								
Van Buren			A	A	A	P	A	D	D	D								
Illinois:																		
Clay	A	A	A			A	A	A										
Franklin				A	A	A	D		D								D	
Jackson				A	A	A	P	D	D	D						D		
Jefferson	A		A		A	A	P		D	D								
Johnson					A	P	A	P	P	A							D	
Marion	P	P	P		P	D	D		D							D		
Massac				A	P	A		A									D	
Pulaski			A	D	D	D	D	D	D						D	D		
Richland	P	A	A			P	A		A	D						A		
St. Clair				P			P	P										
Union	A	A	A			A	P	D	D	D						D		
Washington	A		A						D							D		
Williamson	A		A		A	A	A			P								
Missouri:																		
Butler				A	A	A												
Cape Girardeau			A	A	P	A	A	A	P							D		

See footnote at end of table.

TABLE 4.—*Status of* Macrocentrus ancylivorus *as a larval parasite of the oriental fruit moth as determined at Moorestown, N.J., from infested peach twigs collected in 138 counties, 1930–47* [1]—Continued

State and county	1930	1931	1932	1933	1934	1935	1936	1937	1938	1939	1940	1941	1942	1943	1944	1945	1946	1947
Missouri—Continued																		
Dunklin						A	A	A	A							P		
Jefferson						A	A	A									P	
Lawrence					A				P	A							A	
St. Louis						A	P	A									D	
Scott			A	A	A	A	A	A	D									
Arkansas:																		
Benton			A	A			P											
Lee							P	P	P									
Washington			A	A	A		A											
Louisiana:																		
Morehouse										A	A	A				A		A
Mississippi:																		
Washington														A	A	A		

	1930	1931	1932	1933	1934	1935	1936	1937	1938	1939	1940–47
Counties—number	45	71	74	75	92	74	81	92	89	51	[2] 52
P's—percent	33	23	19	25	14	24	18	14	19	18	8
A's—do	51	52	58	48	50	39	51	48	32	39	24
D's—do	16	25	23	27	36	37	31	38	49	43	68

[1] P=*M. ancylivorus* present in one or more collections but not dominant; A=absent from all collections; D=dominant in one or more collections.

[2] Based on counties where there were observations previous to 1939.

(Smith *1929*, Putnam *1935a*), Connecticut (Garman *1930a*, Schread et al. *1942*), New York (Daniel *1932*), New Jersey (Driggers *1929*, *1930a*, Haeussler *1930*, Brunson *1940*), Delaware (Stearns and Williams *1931*, Rice *1935*, Stearns and Amos *1941*), Maryland (McConnell *1932*, *1934*), Virginia (Bobb *1939*, *1942*), South Carolina (Eddy and Nettles *1931*, Cartwright *1935*, *1938*, *1939*, *1940*, *1945*), Ohio (Stearns and Neiswander *1930*, Neiswander and Vogel *1931*, *1933*, Blackburn *1948*, Weaver *1949*), Michigan (Merritt *1933b*), Tennessee (Butler *1932*, *1933*), and Missouri (Wingo *1941*). *M. delicatus* occurred rather regularly as the dominant parasite of the oriental fruit moth during the 1930's in some peach-growing sections of southern Ohio (Stearns and Neiswander *1930*), Tennessee (Butler *1932*, *1933*), and South Carolina (Cartwright *1938*). Several authors observed that parasitism of the oriental fruit moth by this species was high only during the second generation.

Weaver (*1949*) reported that in central and southern Ohio parasitism of the oriental fruit moth by *delicatus* is gradually decreasing where *M. ancylivorus* is increasing. Boyce and Dustan (*1954*) found that since DDT and parathion have been commonly used in Ontario orchards, *delicatus* has steadily increased its parasitism of the oriental fruit moth in Essex County. *M. delicatus* was exported from the United States to Italy in 1935 and liberated against this host there (Grandi *1937*).

M. delicatus occurs as a common parasite of the extremely abundant *Epiblema strenuana* in ragweed, which is almost always present in or near peach orchards. This alternate host has been reported from New Jersey (Allen and Lott *1930*), Maryland (McConnell *1932*), South Carolina (Nettles *1932*, Cartwright *1935*), Indiana (Montgomery *1933*), Ontario (Putnam *1935a*), Iowa (Decker *1935*), Delaware (Rice *1935*), and Virginia (Bobb *1942*). Schread et al. (*1942*) rarely found it as a parasite of *E. strenuana* in Connecticut, but Putnam found it abundant in that host in Ontario, where it was only a minor parasite of the oriental fruit moth.

There are no published records of the mass propagation of *delicatus*. The material for the few small attempts at colonization was obtained from collections of infested peach twigs or from *E. strenuana* in ragweed. Driggers (*1930a*) thought that he had been able to increase parasitism slightly by small liberations of *delicatus*. He also observed that *delicatus*, which formed cocoons in the fall, failed to overwinter.

The data at the Moorestown laboratory indicate that *delicatus* is the second most abundant parasite in oriental fruit moth larvae (table 3). It was reared from practically every State surveyed. Although parasitism by this species was generally rather low, in some counties it has been for many years the dominant parasite, often destroying 50 percent or more of the oriental fruit moth population. Its center of abundance appears to be central and southern Ohio, eastern Tennessee, and southern Indiana. In Ohio, despite the inclusion of several northern counties of low *delicatus* parasitism in the totals, the average parasitization by *delicatus* was 22.6 percent, and it was reared from 39 percent of all collections.

M. delicatus was usually absent or scarce during the first generation of the oriental fruit moth, but it became abruptly abundant during the second. However, it was sometimes reared in large numbers from late first-generation host larvae collected in late June. In 1940 at Moorestown several orchards were studied throughout the period when peach twigs were succulent. The

study was made by taking collections at 4-day intervals. In most of these orchards the peak of *delicatus* parasitism was from middle to late June at the end of the first generation.

M. delicatus was reared in 1930 from first-generation *E. strenuana* collected from East Longmeadow, Mass., Cinnaminson and Moorestown, N.J., Chambersburg, Coatesville, Greensburg, and York, Pa., Columbus, St. Clairsville, Springfield, and Zanesville, Ohio, and Indianapolis, Ind. In 1932 it was reared from the first generation collected at Cheswold, Del., and Berlin, Md., and from an overwintering generation collected at Moorestown. It was not reared from other alternate hosts studied.

In 1929 and 1930 experimental propagation of *delicatus* was attempted at Moorestown. When the oriental fruit moth was used as a propagation host, either in succulent peach twigs or slices of green apple, parasitism was heavy (60–70 percent), and the parasite was as easily propagated as was *M. ancylivorus*. However, there was a strong tendency for *delicatus* when propagated in the oriental fruit moth in late summer to develop precociously to the cocoon stage during hibernation. Very few that developed to cocoons at such a period could be successfully overwintered. From 5,207 oriental fruit moth cocoons reared in the propagation tests and carried overwinter, 1,178 *delicatus* adults were obtained. In 1944 an unsuccessful attempt was made to propagate *delicatus* in *Gnorimoschema operculella*. From one lot stocked with 43 females, 4 *delicatus* females and 1 male were reared.

Macrocentrus instabilis Muesebeck

(Fig. 2)

The *Macrocentrus* species reared from the oriental fruit moth in New Jersey (Driggers *1929*) and mentioned by Haeussler (*1930*) as occurring in this host in New Jersey, Ontario, and Virginia was described by Muesebeck (*1932*) as *Macrocentrus laspeyresiae*, and later he (*1935*) listed it as synonymous with *Macrocentrus instabilis*. Muesebeck et al. (*1951*) and Krombein et al. (*1958*) stated that *instabilis* occurs from New York and Ohio to Florida and Texas and is in Washington. They listed 12 hosts, including the oriental fruit moth. According to these records *instabilis* is exclusively a primary parasite of small Lepidoptera whose larvae are concealed as fruitworms, stem borers, casebearers, or leaf skeletonizers. Six of the hosts are phycitids of the genus *Acrobasis*. The others are scattered in the families Olethreutidae, Coleophoridae, and Cosmopterygidae. Most are insect pests. Boyce (*1947b*) in Ontario and Jaynes and Marucci (*1947*) in West Virginia found *instabilis* unimportant as a parasite of *Carpocapsa pomonella*. Other records of its parasitism of the oriental fruit moth include those by Butler (*1933*) from Tennessee and Wingo (*1941*) from Missouri.

Nickels et al. (*1950*) reported that in Texas it was a common parasite of *Acrobasis caryae*, with an average parasitization of about 1.5 percent of overwintering larvae, 4.3 percent of the first generation, and 2.8 percent of later transforming generations. During the summer the period from oviposition to mature larvae required about 21 days and from oviposition to emergence 28 to 36 days. Females outnumbered males 142 to 103. Mating occurred within 2 days of emergence. Full-grown larvae issued from full-grown host larvae or pupae. Second- and third-instar larvae were usually selected for oviposition, and only one adult emerged from each host.

Based on the rearing studies at the Moorestown laboratory, *instabilis* occurred as a parasite of the oriental fruit moth in Massachusetts, Connecticut, New York, New Jersey, Pennsylvania, Maryland, Virginia, West Virginia, North Carolina, South Carolina, Georgia, Ohio, Kentucky, Tennessee, Indiana, Michigan, Illinois, Missouri, and Arkansas, and it was about the sixth most abundant larval parasite. Although rarely the dominant parasite of the oriental fruit moth, it occasionally parasitized more than half of the larvae. It was most abundant in Ohio, Tennessee, Illinois, and New York, where it occurred, respectively, in 13, 12, 10, and 9 percent of all the collections and parasitized 5.9, 8.3, 5.9, and 5.1 percent in the collections where it was present.

Macrocentrus pallisteri DeGant

(Fig. 2)

Muesebeck et al. (*1951*) summarized distributional and rearing records of *Macrocentrus pallisteri*. They cited its occurrence from Massachusetts and eastern Canada to Missouri and Kansas and in California and Texas, to which Krombein et al. (*1958*) added Florida. The host records include the oriental fruit moth and three other olethreutid stem borers commonly infesting weeds near peach orchards, namely *Epiblema otiosana*, *E. scudderiana*, and *E. strenuana*. Wingo (*1941*) listed it as a parasite of the oriental fruit moth in Missouri.

From the quarter million insects emerging from the field-collected oriental fruit moths reared at the Moorestown laboratory, six *pallisteri* specimens were identified. These were obtained from Avon Lake and South Amherst, Ohio, in 1930, Benton, Ill., in 1936, Cape Girardeau, Mo., in 1934, and Jackson, Mo., in 1936 and 1938. In 1936 the host relationship was positively confirmed for the specimens from Benton and Jackson by an examination of host remains. Although *pallisteri* is an uncommon parasite of the oriental fruit moth, it so closely resembles *Macrocentrus ancylivorus* that probably some specimens have been erroneously credited to that species.

In 1930 and 1932 numerous *pallisteri* parasites were reared at the Moorestown laboratory from *E. scudderiana*, a common gall-forming borer of goldenrod (*Solidago*). Although this alternate host is usually abundant near peach orchards, there seems to be no record of the rearing of *pallisteri* from oriental fruit moths in the Eastern and Southern States.

Eubadizon pleurale Cresson

(Fig. 4)

The *Eubadizon pleurale* adult is a slender wasp resembling the species of *Macrocentrus* that are parasitic on the oriental fruit moth. It is readily separated from them by the presence of only one cubital cell (fig. 4, *A*). It also differs from the American species of *Macrocentrus* that parasitize this host in having a conspicuous black head and abdomen.

Muesebeck et al. (*1951*) and Krombein et al. (*1958*) found this species distributed from Quebec, Ontario, Alberta, and Idaho to Florida. They listed only three hosts, all olethreutids—the oriental fruit moth, *Carpocapsa pomonella*, and *Ancylis comptana fragariae*. Apparently it is rarely present in the last two. In *C. pomonella* it was reared only once by Jaynes and Marucci (*1947*) from West Virginia. Although thousands of field-collected specimens of *A. comptana fragariae* were reared at the Moorestown laboratory, *pleurale* was never recovered from them.

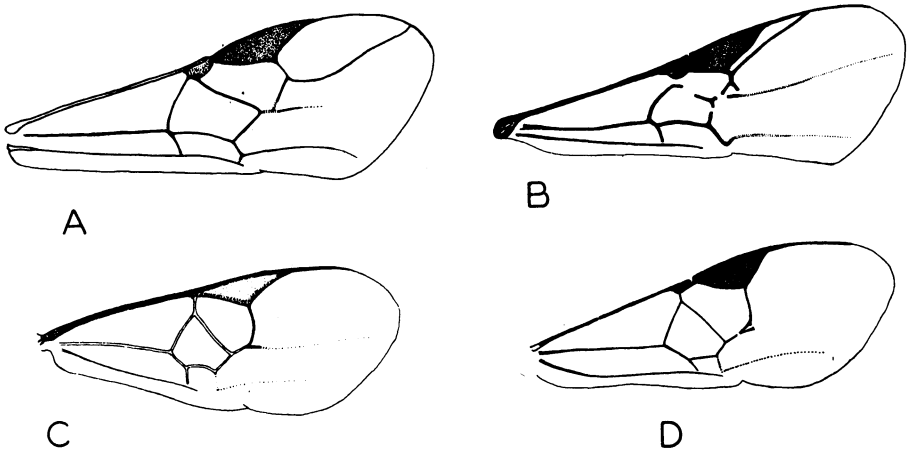

FIGURE 4.—Forewings of braconid parasites of the oriental fruit moth: *A, Eubadizon pleurale; B, Agathis diversa; C, Apanteles epinotiae; D, Microgaster ecdytolophae.*

Stearns (*1919*) reported rearing *Eubadizon gracilis* Provancher from the oriental fruit moth in eastern Virginia in 1919. Between then and 1930 various workers reported rearing *Eubadizon* from this host. In New Jersey it was reared by Stearns (*1927*, *1928*), Driggers (*1929*), and Haeussler (*1930*), in Ontario by Smith (*1929*), in Georgia by Snapp and Swingle (*1929*), in Connecticut by Garman (*1930a*), and in Ohio by Stearns and Neiswander (*1930*). These parasites were variously identified as *Eubadizon* sp., *E. gracilis*, and *E. pleuralis*, but they were almost certainly all the same species now identified as *pleurale*. The oriental fruit moth was the earliest known host and has always been the only one from which *pleurale* was commonly reared. In addition to the records mentioned above, it was reared from this host in New York (Daniel *1932*), Maryland (McConnell *1932*), Tennessee (Butler *1933*), Missouri (Wingo *1940*), and Delaware (Stearns and Amos *1941*). Stearns reared only one specimen in Delaware. Daniel found it a fairly common oriental fruit moth parasite in Niagara County, N.Y. Garman (*1940*) listed it among the five most important parasites in Connecticut, and Wingo (*1941*) stated that it was among the four most abundant in Missouri.

In the studies made at the Moorestown laboratory *pleurale* was found to be a broadly distributed parasite of the oriental fruit moth, occurring in 17 States from Massachusetts to Illinois and south to Georgia, Tennessee, and Missouri. It was rated as about the seventh most abundant larval parasite (table 3). In the collections where this parasite was present, it parasitized on an average 4.2 percent of the larvae. On the same basis the parasitization by this species in collections from New York, Missouri, and Indiana were 14.4, 12.3, and 6.7 percent and in those from New Jersey and Delaware only 0.5 and 0.4 percent, respectively. Rates of parasitization in excess of 20 percent were common in three counties in southeastern New York, seven counties in southern Indiana and northwestern Kentucky, and scattered counties in Missouri. The high rates occurred almost exclusively from late June to late July.

Very little about the biology of *pleurale* is known. It apparently

attacks larvae in their tunnels in peach twigs. The full-grown parasites issue from the host larvae after they have formed their cocoons, and the parasite cocoon is spun beside the host remains. The cocoon is light brown to white, with thin, flexible, translucent walls. It is sometimes embedded in a small amount of woolly silk. On emerging, the parasite roughly chews away the entire anterior end.

Genus AGATHIS

Five species of *Agathis* have been reared as parasites of the oriental fruit moth. Three are native species recovered from this host only occasionally, and two are introduced species, which have been recovered in restricted areas.

The species of *Agathis* differ from other parasites of the oriental fruit moth in having the radius close to and parallel to the posterior apical margin of the stigma (fig. 4, *B*). The adults are clumsy and rather sluggish. They attack young larvae and emerge from cocooned larvae, spinning their white cocoons within the cocoon of the host. In one species unfertilized females produce females, and males occur rarely and are probably not functional. The ovipositor is relatively long. The *Agathis* species commonly attack oriental fruit moth larvae in fruit, as well as those in twigs.

KEY TO SPECIES OF AGATHIS ATTACKING ORIENTAL FRUIT MOTH LARVAE

(Adapted from Muesebeck (*1927*))

1. Head, thorax, and coxae not entirely black or piceous 2
   Head, thorax, and hindcoxae black or piceous 3
2. Propodeum with two conspicuous medial carinae; second abdominal tergite more or less ferruginous; males common ..... *rubripes* Cress.
   Propodeum without paired medial carinae; second abdominal tergite black; males rare ..... *diversa* (Mues.)
3. Temples without tuberculate bulge; propodeum without longitudinal carinae .. 4
   Temples with prominent or rounded tubercle; propodeum with two medial longitudinal carinae ..... *annulipes* (Cress.)
4. First abdominal tergite somewhat flattened, conspicuously shagreened, scarcely twice as long as apical width; second segment ferruginous ..... *cincta* (Cress.)
   First abdominal tergite arched, more or less aciculate, more than twice as long as apical width; second segment yellowish white ..... *festiva* Mues.

Agathis annulipes (Cresson)

Muesebeck et al. (*1951*) and Krombein et al. (*1958*) stated that *Agathis annulipes* occurs from Quebec to Florida and west to South Dakota and Kansas. They listed as hosts 10 Lepidoptera whose larvae are small and live as borers or leaf rollers in a sheltered environment. They are mostly olethreutids or tortricids, but one gelechiid and one phycitid were also listed as hosts. Wingo (*1940*) reported having reared *annulipes* from the oriental fruit moth in Missouri.

At the Moorestown laboratory only three specimens were reared from oriental fruit moth larvae collected in peach twigs—one each from Clemson, S.C., Newton, Ohio, and Linton, Ind. All were reared from lots in which the oriental fruit moth was the only host reared, and the host of the Ohio specimen was proved by examination of the host remains. All three were determined by Muesebeck.

Agathis cincta (Cresson)

Muesebeck et al. (*1951*) stated that *Agathis cincta* occurs from

Quebec to Florida, west to South Dakota and Kansas, and in Oregon. In the catalog by Muesebeck et al. (*1951*) and its supplement by Krombein et al. (*1958*), 17 species of small Lepidoptera are listed as hosts, of which 8 are parasites of casebearers of the genus *Coleophora*, 4 hosts are gelechiids, 3 are tortricids, 1 is a phycitid, and 1 is an olethreutid, the oriental fruit moth. *A. cincta* was recorded by McConnell (*1932*) as a parasite of oriental fruit moth larvae in Maryland and by Merritt (*1933b*) as having been reared from this host in Michigan.

Although *cincta* was reared at the Moorestown laboratory more frequently as a parasite of the oriental fruit moth than any other indigenous species of *Agathis*, parasitism by the species was uncommon. In over a quarter million insects reared, 16 were parasitized by this species. No collection produced more than one specimen. *A. cincta* was reared as a parasite of this host from the following 12 counties: Burlington and Mercer, N.J., Rockingham, Va., Cuyahoga, Franklin, Knox, Ottawa, and Richland, Ohio, Floyd and Martin, Ind., Pulaski, Ill., and Jefferson, Mo.

Agathis rubripes Cresson

Muesebeck et al. (*1951*) listed *Agathis rubripes* as a parasite of *Coleophora cratipennella* Clemens and the oriental fruit moth. It must be exceptionally rare as a parasite of the latter, since among the many hundreds of thousands of specimens collected and reared by workers in the Eastern States, there seems to be only one record of rearing it from this host. Daniel (*1932*) reared a single specimen from larvae collected in Niagara County, N.Y., in 1930. He explained that the host material was not isolated before emergence, and there was no identification with host remains. This species was never reared as a parasite of the oriental fruit moth at the Moorestown laboratory.

Agathis diversa (Muesebeck)

(Fig. 4)

Agathis diversa was discovered in 1932 by Haeussler (*1940*) during his explorations in Japan for parasites of the oriental fruit moth. He observed that it was a solitary parasite and formed its cocoon within the cocoon of the host. He was able to propagate it when young oriental fruit moth larvae just under the skin of whole apples were exposed to it. He found that this parasite hibernated readily in the cocoons of this host and that unfertilized females produced only females. The parasite was found in only two prefectures, which were located on the island of Honshu. During 1933 and 1934 only 134 were reared from field collections.

At the Moorestown laboratory *diversa* was readily propagated on the oriental fruit moth by exposing either succulent peach twigs or slices of immature apple heavily infested with young larvae (Allen et al. *1940*). Among the many thousands propagated, a male was occasionally found. From 1934 to 1939 about 48,500 *diversa* adults were propagated at the Moorestown laboratory and released in numerous colonies in the peach-growing areas of the Eastern States. In 1934 Garman (*1936*) started propagating *diversa* for release in Connecticut. During the 1930's and early 1940's 82,000 were released in Connecticut orchards (Garman et al. *1953*).

A. diversa was recovered regularly from infested peach twigs collected after liberation near where it was released, and 20-percent para-

sitization by this species in such collections was not uncommon. However, in most localities it was not recovered from infested peach twigs during the year following liberation or subsequently. The single exception observed by the author was at Leslie, Mich., where a few were recovered in 1939 from an orchard that had received *diversa* in 1937. Garman et al. (*1940*) noted similar results in Connecticut, but observed at least one instance when *diversa* persisted in an orchard as a parasite of the oriental fruit moth in peach twigs for 3 years. Allen and Yetter (*1949*) found in 1947, 8 years after the last colonization, that it had become established in Burlington County, N.J., as a parasite of the oriental fruit moth attacking very late peaches, but it did not occur in transforming oriental fruit moths reared from peach twigs and immature peaches or in hibernating oriental fruit moths in apple drops.

Agathis festiva Muesebeck

Agathis festiva, which Krombein et al. (*1958*) stated occurs in China and India, is now probably established locally in New York.

In January 1951, 11 females and 2 males were received at the Moorestown laboratory from S. E. Flanders of the Citrus Experiment Station at Riverside, Calif. He [3] stated that they emerged in California from a shipment of *Carpocapsa pomonella* cocoons originating in Tsinan, Shantung, China, where they were obtained from infested pears and apples and reared and shipped to him. Flanders stated that the host adults, numbering 1,000–2,000, were not all checked, and several species of Lepidoptera may have been present. These could readily have included some oriental fruit moths.

At the Moorestown laboratory the 11 females and 2 males were immediately placed in a suitable cage with small green apples heavily infested with young oriental fruit moth larvae. Evidently the males were impotent, because in the 240 progeny reared only males were obtained. On February 1 and 2 the two surviving females were mated with their earliest emerging male progeny. These nearly spent females, which mated so late in life, produced most unexpectedly 44 female progeny. This was the nucleus of subsequent propagation.

From 1951 to 1955, inclusive, the annual propagation of *festiva* at Moorestown ranged from 19,000 to 50,000 adults. During this 5-year period 162,000 were produced, of which 49.8 percent were females. Since the propagation ratios were relatively low and standby rearing was maintained throughout the year, the numbers available for liberation during the season favorable for release were less than half the total produced.

The method used in propagating was a modification of that described for *Agathis diversa* (Allen et al. *1940*). Host eggs were obtained on whole mature apples impaled on spikes, closely set on small platforms, which had been exposed to cages of ovipositing oriental fruit moths. As soon as the hatching larvae penetrated the apple and frass was visible, the platforms were exposed to ovipositing parasites. The infested apples were then removed and mixed with suitable amounts of fresh uninfested apple. Better results were obtained with whole than with sliced apples.

Liberations were made from 1951 to 1955, inclusive, in the 8 States, 28 counties, and 88 localities listed below. Since there is now a higher

[3] Personal communication dated Feb. 2, 1955.

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seasonal average of oriental fruit moth infestation in unsprayed apple orchards than in peach, most of the liberations, particularly during the last 3 years, were in abandoned apple orchards. The liberations were made at the following places:

Connecticut:
- Fairfield: New Canaan '52
- Hartford: South Glastonbury '52, South Windsor '52, West Hartford '55
- Middlesex: Chester '52, West Rocky Hill '55
- New Haven: Guilford '55, Seymour '55
- New London: East Lyme '55, Flanders Village '52, Montville '52

New York:
- Monroe: Adams Basin '55
- Niagara: Newfane '55, Somerset '55
- Orange: Middle Hope '53, '55, Vail's Gate '53, '55
- Orleans: Albion '55
- Ulster: Ardonia '53, Highland '55, Lattintown '53, '55, Marlboro '53, '55
- Wayne: Sodus '55

New Jersey:
- Atlantic: Hammonton '51
- Burlington: 17 localities '51
- Camden: Berlin '51, Blue Anchor '51, Ellisburg '51, Elm '51, Haddonfield '51, Waterford '51, Winslow '51
- Gloucester: Aura '51, Cross Keys '51, Franklinville '51, Glassboro '51, Harding '51, Mickleton '51
- Salem: Elmer '51, Pittsgrove '51
- Sussex: Andover '53, Fredon '53, Glenwood '53, Hamburg '53, Newton '53
- Warren: Hackettstown '53, Hazen '53, Oxford '53, Port Murray '53, Washington '53

Pennsylvania:
- Adams: Fairfield '52
- Franklin: Fayetteville '52, Scotland '52

Maryland:
- Washington: Big Pool '54, Hagerstown '54, Hancock '54, Huyett '54, Indian Springs '54, Ringgold '52

West Virginia:
- Berkeley: Gerrardstown '54, '55, Hedgesville '54, Martinsburg '54, Shanghai '55
- Jefferson: Kearneysville '54

Virginia:
- Frederick: Grimes '55, White Hall '55

North Carolina:
- Alexander: Taylorsville '51
- Surry: Mt. Airy '51
- Wake: McCullers '51, Raleigh '51
- Wilkes: Moravian Falls '51, Pore's Knob '51, Wilkesboro '51

Table 5 shows the number of adults liberated and the number of orchards receiving parasites. A total of 75,956 were released in 195 orchards.

After the first liberations, *festiva* was reared several times from unsprayed apples collected in orchards receiving parasites, and the hosts, proved by isolation and examination of host remains, were the oriental fruit moth and *Grapholitha prunivora* (Walsh). Most of the recoveries were made from samples taken within a few weeks of and during the same season as the liberation. In one instance a single specimen was reared from an infested apple taken at Evesboro, N.J., in 1952 during the second season after liberation. Subsequent collections in all these locations but one contained no *festiva* specimens. Despite the recoveries noted by Hoyt (*1954*), the species has not been considered established in the United States until 1957. In July 1957, 2 years after colonization in an abandoned quince orchard at Somerset, N.Y., eight *festiva* specimens were recovered from the oriental fruit moth in a sample of quinces collected and

TABLE 5.—*Number of* Agathis festiva *adults liberated and number of orchards receiving parasites, 1951–55*

State	1951		1952		1953		1954		1955	
	Adults	Orchards	Adults	Orchards	Adults	Orchards	Adults	Orchards	Adults	Orchards
Connecticut			5,538	11					2,951	5
New York					6,531	10			5,346	10
New Jersey	19,050	100			4,786	11				
Pennsylvania			394	4						
Maryland			177	1			14,404	12		
West Virginia							11,890	9	1,842	2
Virginia									1,195	3
North Carolina	1,852	17								
Total	20,902	117	6,109	16	11,317	21	26,294	21	11,334	20

shipped to the Moorestown laboratory by E. H. Smith of the New York Agricultural Experiment Station at Geneva. In this sample *festiva* parasitized 3 percent of the host reared and was the most common parasite. This appears to be a local establishment.

Genus APANTELES

The genus *Apanteles* contains a large number of species, many of which are important parasites of crop pests. The American species attacking the oriental fruit moth are the smallest of the braconid parasites. They have black bodies and the abdomens are relatively small. The wing venation, except for the radius, is generally translucent and inconspicuous (fig. 4, *C*). Muesebeck (*1920*) made several observations on the biology of this genus. He stated that insofar as is known all *Apanteles* species are exclusively parasites of Lepidoptera larvae. The species tend to be restricted to a group of hosts that are closely related phylogenetically or in larval habitats. Many species attack free-living caterpillars, whereas others parasitize larvae protected within their food medium, such as leaf rollers, leaf miners, stem borers, or bud moths. They may be gregarious or solitary, and there is great variety in the texture and color of the cocoons.

It would seem that the oriental fruit moth, which is well concealed in deep tunnels most of its larval life, would be relatively immune to the *Apanteles* species, which are small and have relatively short ovipositors. However, Haeussler (*1940*) found that two species were fairly effective against this host in some localities in Japan, with rates of parasitization approximating 20 percent. They were sometimes the dominant parasites.

Four North American species have been reared from the oriental fruit moth, but none are important parasites of this host. They attack larvae infesting peach twigs and form their cocoons within that of the host.

Apanteles epinotiae Viereck

(Fig. 4)

Apanteles epinotiae occurs from Maine to Florida and west to Illinois, Nebraska, and Texas (Muesebeck et al. *1951*, Krombein et al. *1958*). Muesebeck listed eight Microlepidoptera as hosts, three of which are olethreutids, two phycitids, and one each of the families Gelechiidae, Phaloniidae, and Pterophoridae. This group includes casebearers, twig borers, and the shuckworm, in which the larvae are concealed, and at least one surface feeder, *Dichomeris ligulella* Hübner. *A. epinotiae* has also been recorded from another gelechiid, the leaf miner *Keiferia lycopersicella* (Busck) (Thomas *1936*); from a hyponomeutid leaf miner, *Argyresthia thuiella* (Packard) (Underhill *1943*); and from a bud moth in sunflower, *Suleima helianthana* (Satterthwait *1948*). Stearns and Neiswander (*1930*) reported it as a parasite of the oriental fruit moth.

The most common *Apanteles* species parasitic on the oriental fruit moth in the United States is *epinotiae*. However, it was not found abundant enough to be important generally or even in one locality. In the rearing of insects from infested twigs at the Moorestown laboratory, it was recovered from 15 counties—one county in Kentucky, one in Ohio, and the others scattered east of the Alleghenies in nine States from Massachusetts to South Carolina. Thirty *epinotiae* specimens were reared. They were obtained from only 0.5 percent of the collections made and

2, 4, and 6 percent, respectively, of the properties, localities, and counties from which samples were taken. It was most frequently reared from Rockland County, N.Y., from 1933 to 1936. The remains of two were examined in 1933. They issued singly from very small cocooned larvae of the oriental fruit moth. In numerous specimens only one parasite issued from each host. The cocoons were small and opaque white. They were found in the host cocoon. The parasite emerged through a clear circular hole at the apex of the cocoon.

Apanteles clavatus (Provancher)

Apanteles clavatus occurs in Canada and from Maine to South Carolina, west to Ohio and Tennessee, and in California and Oregon. It has been reported as a parasite of one tortricid and two olethreutid hosts.

At the Moorestown laboratory between 1930 and 1938 *clavatus* was reared from eight oriental fruit moth larvae, apparently always as a solitary parasite. Host relationships were not proved by microscopic examination of any host remains, but the number of recorded rearings removes all doubt as to the host relationship. *A. clavatus* was reared in collections from Milford, Conn., Richwood, N.J., Gramling, S.C., Mt. Airy, Ga., Paducah, Ky., Port Clinton, Ohio, and Kimmswick, Mo.

Apanteles cacoeciae Riley

Muesebeck et al. (*1951*) stated that *Apanteles cacoeciae* occurs from Quebec to South Carolina and west to South Dakota and Colorado. Muesebeck et al. (*1951*) and Krombein et al. (*1958*) listed nine Lepidoptera as hosts. These include one gelechiid, one phycitid, and the rest about equally divided between tortricids and olethreutids. The larvae attacked are leaf rollers, stem or twig borers, and casebearers. Muesebeck (*1920*) noted that the cocoons are white, thin, and firmly held together in groups of three to six. Judd (*1951*) reared as many as 18 from one larva of *Gnorimoschema gallaesolidaginis* Riley. Daniel (*1932*) reared *cacoeciae* from four oriental fruit moth larvae in 1930 and nine in 1931 in peach twigs in Niagara County, N.Y.

At the Moorestown laboratory *cacoeciae* was reared only four times as a parasite of the oriental fruit moth. All were identified by Muesebeck. In 1935 the host relationship was proved by the microscopic examination of the remains of this host with a *cacoeciae* specimen reared from East Williamson, N.Y. The parasite was gregarious; it formed a cluster of six cocoons. In 1938 one larva was parasitized in each of the following localities: Clemson, S.C., Kevil, Ky., and Olney, Ill. Some of these were apparently solitary.

Apanteles polychrosidis Viereck

Apanteles polychrosidis occurs from Ontario to North Carolina, west to South Dakota and Missouri, and also in Washington and Oregon (Muesebeck et al. *1951*). Muesebeck et al. listed nine lepidopterous hosts—four tortricids, three olethreutids, a gracilariid, and a lyonetiid—most of which are insect pests. They include leaf rollers, leaf miners, and *Paralobesia viteana* (Clemens). These authors also listed the oriental fruit moth among the hosts. *A. polychrosidis* must be uncommon as a parasite of this last host, since none of the numerous workers who have studied its parasites appear to have mentioned *polychrosidis*, and it has never been reared at Moorestown.

Genus MICROGASTER

Two species of *Microgaster* have been reared as primary parasites of oriental fruit moth larvae. The adults are small black braconids with small abdomens and resemble *Apanteles*, but the wing venation is more generally pigmented and there is an areolet in the forewing (fig. 4, *D*). Little is known of the biology of either, but a Eurasian species, *Microgaster tibialis* Nees, commonly parasitic in *Pyrausta nubilalis*, has been reared in large numbers and studied in detail. Vance (*1932*) observed that fertile *M. tibialis* females produce both sexes and unfertilized females only males. The female attacks young exposed larvae of *P. nubilalis* and prefers second-instar hosts. The parasite punctures a squirming larva and without paralyzing it deposits an egg in the body cavity. More than one egg per host may be deposited, but only one larva matures. There are three larval instars. The parasite overwinters as a prepupa within its cocoon.

Microgaster ecdytolophae Muesebeck

(Fig. 4)

The reported distribution of *Microgaster ecdytolophae* is from Nova Scotia to Florida, west to Ontario, Indiana, and Texas, and in Central America and the West Indies (Muesebeck et al. *1951*). Muesebeck et al. (*1951*) and Krombein et al. (*1958*) listed nine hosts, all Lepidoptera whose larvae are sheltered, such as fruitworms, stem borers, casebearers, leaf blotch miners, and leaf skeletonizers. Three are olethreutids, two gelechiids, and one each of the families Gracilariidae, Coleophoridae, Phycitidae, and Pyraustidae. It was also reported (Brett *1946*) as a parasite of *Walshia amorphella* Clemens, a momphid that lives in galls on the twigs of the indigo bush (*Indigofera*) in Oklahoma, and *ecdytolophae* was reared from *Carpocapsa pomonella* in West Virginia (Jaynes and Marucci *1947*). It has been reported infrequently as a parasite of the oriental fruit moth. In Delaware one specimen was reared among the more than 9,000 parasites recovered in 10 years' work (Stearns and Amos *1941*). Wingo (*1941*) reared it from the oriental fruit moth in Missouri.

The parasite-rearing work at the Moorestown laboratory indicated that *ecdytolophae* as a parasite of the oriental fruit moth was nowhere abundant enough to be important. Usually only one was reared from a collection of infested peach twigs. A total of 55 were reared in 40 field collections from 32 properties, 23 localities, 18 counties, and 8 States from Pennsylvania to Virginia and west to Illinois. It was recovered from only one county (Wicomico, Md.) east of the Appalachian foothills. It was much more common in Virginia than any other State. The 32 specimens recovered from Virginia were reared from 21 collections, 16 properties, and 8 localities.

M. ecdytolophae attacked larvae of the oriental fruit moth boring in peach twigs. After the host had cocooned, the full-grown parasite issued and spun its cocoon beside the host remains. Although small, it was a solitary parasite. However, in one instance two issued from the same host larva. The cocoon was white and usually opaque at the anterior end but translucent posteriorly.

Microgaster epagoges Gahan

The distribution and hosts of *Microgaster epagoges* have been summarized by Muesebeck et al. (*1951*) and Krombein et al. (*1958*).

It is distributed from Massachusetts to South Carolina, west to Ontario, Iowa, and Colorado, and in British Columbia. There are 10 hosts, of which 7 are tortricids and one each of the families Olethreutidae, Pyraustidae, and Gelechiidae. In addition, Baker et al. (*1949*) found it parasitic on *Pyrausta nubilalis*, another pyraustid, in the Lake States and New England. Although this species is generally a parasite of leaf rollers, it has been reared from stem and twig borers.

Among the quarter million insects obtained at the Moorestown laboratory from field collections of oriental fruit moth larvae, one *epagoges* specimen (Oriental Fruit Moth Investigations No. 2242) was reared from infested peach twigs taken at Spencer, Ind., on June 5, 1935. There seems to be no reason to question the record, because the host was isolated, the host relationship was proved by examination of larval remains, and the specimen was determined by Muesebeck.

Ascogaster quadridentata Wesmael

(Fig. 5)

The adult of *Ascogaster quadridentata* is robust, with a black, coarsely sculptured body, four prominent teeth on the posterior margin of the propodeum, and a forewing as in figure 5, *F*. The abdomen is ovate, with only one visible tergite. *A. quadridentata* is a common European parasite of *Carpocapsa pomonella* and was probably introduced into North America accidentally with this host many years ago (Boyce *1936*). In North America much of the literature appears under the name *Ascogaster carpocapsae* (Viereck). Muesebeck et al. (*1951*) and Krombein et al. (*1958*) indicated a somewhat restricted distribution in North America from Nova Scotia and Ontario to Virginia and west to Indiana and in Oregon and Washington. It has been reported

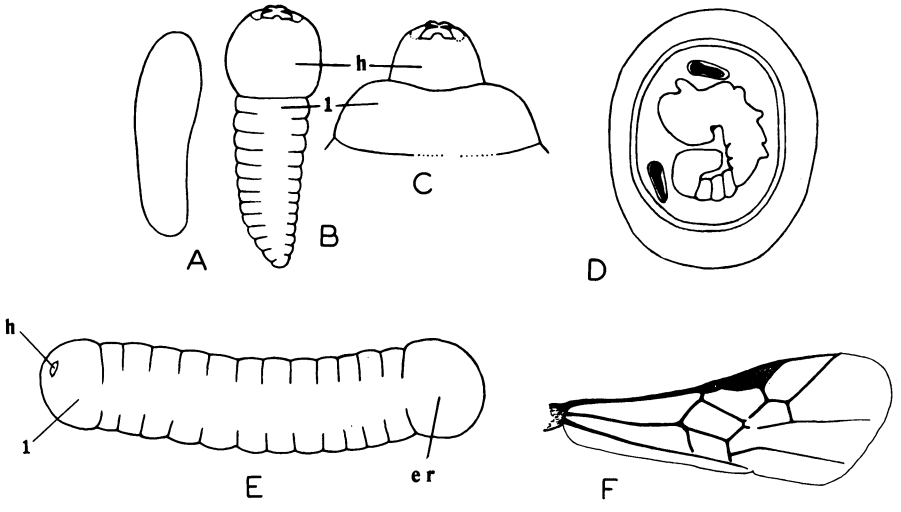

FIGURE 5.—*Ascogaster quadridentata: A*, Egg; *B*, young first-instar larva; *C*, head (*h*) and first thoracic segment (1) of first-instar larva one-third grown; *D*, two eggs 21 hours old beside host embryo in *Carpocapsa pomonella* egg; *E*, full-grown first-instar larva, showing head (*h*), first thoracic segment (1), and evaginated rectum (*e r*); *F*, forewing. (*A*, *B*, *C*, and *E* redrawn from Rosenberg (*1934*); *D* redrawn from Cox (*1932*).)

from California (Hensill *1933*) and British Columbia (Webster and Shenefelt *1945*). Haeussler (*1940*) did not find it in Korea or Japan.

Muesebeck et al. (*1951*) listed only six North American hosts, four of which are olethreutids (*C. pomonella*, *Grapholitha prunivora*, *Paralobesia viteana*, and the oriental fruit moth), one a gelechiid (*Gelechia*), and one a pyraustid (*Desmia funeralis* (Hübner)). Rosenberg (*1934*) gave a much more extensive list of recorded hosts. *A. quadridentata* occurs naturally on *Laspeyresia nigricana* (Stephens) in England, and a few have been recovered after liberations of the imported parasites in Canada (Wishart *1943b*).

Three authors have given detailed biological and anatomical information on this species. Cox (*1932*) studied it as a parasite of the oriental fruit moth and *C. pomonella* in western New York, Rosenberg (*1934*) as a parasite of *C. pomonella* in France, and Boyce (*1936*) as a parasite of the oriental fruit moth in the Niagara peninsula of Ontario. They agreed in most of the details.

Females mate almost immediately after emerging, and oviposition may begin within 24 hours of mating. Fertilized females produce both sexes in a 1:1 ratio. Unmated females produce only males, which are smaller than the males from fertile females, but which mate normally. Cox found that at 70° to 75° F. females lived on an average for 31 days and males for 22 days.

The adult oviposits within the host egg (fig. 5, *D*). It apparently will deposit in eggs of any age. It has even been observed attempting oviposition in eggshells and in the substratum, from which eggs have been rubbed away. The egg (fig. 5, *A*) is smooth and dull white, with an outline like the imprint of a moccasin. Rosenberg counted 325 eggs deposited by one female and 733 by another. Usually only one egg is deposited at a time. However, since the female is unable to distinguish previously parasitized eggs, in repeated trips over host eggs several eggs may be deposited in one host. Females deposit readily in freshly deposited host eggs. However, Boyce obtained a better rate of propagation when eggs were 38 to 48 hours old when exposed than when newly deposited eggs were used. Cox and Rosenberg found that the parasite egg was deposited only in the unorganized material surrounding the embryo, but Boyce observed that eggs were also frequently deposited within the embryo.

The newly hatched larva (fig. 5, *B*) is subconical, about 0.2 mm. long, with a very large head and well-developed mandibles. One to several larvae may invade one host embryo. This stage becomes established within the embryo before hatching and persists until the host larva is mature. However, in that period it grows to a slender larva about 2.0 mm. long. Rosenberg observed that during this instar the head becomes dwarfed in relation to the rest of the body and the rectum conspicuously evaginated (fig. 5, *B*, *C*, *E*). Several workers observed that its presence in *C. pomonella* invariably dwarfs the larva to about one-third its normal size, and that reliable estimates of parasitism can be made by counting the number of small larvae.

The second instar is an internal parasite of cocooned larvae. Cox reported two instars during this period. Several records agree that the last instar issues from the larval host, and as an ectoparasite it rapidly consumes the remaining tissues. Cushman (*1912*) observed that this external feeding was completed in 1 day, during which the

larva trebled in size. The cocoon is glossy white and is spun within the host cocoon beside the remains of the host larva. Only one parasite matures per host.

A. quadridentata from the Eastern States was colonized against *C. pomonella* in Washington and British Columbia in 1926 or earlier and became well established in Washington by 1927 (Newcomer *1928*). Cox (*1932*) and subsequently several other authors observed that parasitism by this species was greatly reduced in orchards sprayed with arsenate of lead and to a lesser extent by oils. Garman and Brigham (*1935*) confirmed the identity of the European *quadridentata* with *A. carpocapsae* by crossing females from European stock with males of American *A. carpocapsae*. The progeny contained a normal ratio of males and females, indicating the mating had been normal. Boyce (*1941*) found that the effectiveness of this parasite in Ontario was lessened by attacks of several species of the hyperparasite *Perilampus*. There are many other references to the occurrence of *quadridentata* in *C. pomonella*. *A. quadridentata* from *L. nigricana* was exported from England from 1936 to 1939, and it was colonized against this host in British Columbia (Wishart *1943b*).

A. quadridentata has been recorded as a parasite of the oriental fruit moth in Maryland (Garman *1918*, McConnell *1932*), Virginia (Wood and Selkregg *1918*), New Jersey (Stearns *1927*, *1928*, Haeussler *1930*), Ontario (Smith *1929*, Steenburgh *1930a*, *1931*), Georgia (Alden *1930*), New York (Daniel *1930*, *1932*, *1936*, Daniel et al. *1933*), Ohio (Stearns and Neiswander *1930*), South Carolina (Eddy and Nettles *1931*), and Michigan (Merritt *1933b*).

In the rearing work at the Moorestown laboratory from field-collected peach twigs, *quadridentata* was recovered from the Atlantic Coast States, Massachusetts to Virginia, inclusive, and from Ohio, Michigan, Indiana, Illinois, Kentucky, and South Carolina. In Kentucky it was reared in two collections from Lexington, in Illinois from one collection at New Burnside, and in South Carolina from Greer, Clemson, and Gramling. As a parasite of the oriental fruit moth in peach twigs, it was recovered from 48 counties, 84 localities, 109 properties, and 146 collections, which were, respectively, 10, 14, 9, and 3 percent of the total for the survey. In the collections where this parasite occurred, the average parasitization by *quadridentata* was 1.9 percent. In individual collections, rates in excess of 5 percent were common, but there were few above 10 percent. The highest parasitization from infested peach twigs was from an unusually late-season lot collected at Gramling, S.C., on September 2, 1936. Of the 136 insects reared, 30 percent were *quadridentata*.

In the rearing of fruitworms from samples of unsprayed apples from 1952 to 1957, *quadridentata* was the most abundant parasite of the oriental fruit moth and *C. pomonella*, and it was also an occasional parasite of *G. prunivora*. This survey was made in seven States from Connecticut to North Carolina, inclusive, and consisted of 210 samples of unsprayed apples and 1 sample of unsprayed quince from 26 counties, 66 localities, and 94 properties, from which 3,452 oriental fruit moths and 6,634 *C. pomonella* cocoons were reared. Comparison of results obtained from these insects in apple with the results from oriental fruit moths in peach seems to support the opinion of Daniel et al. (*1933*) that

quadridentata adults are attracted to apple orchards.

The observations at the Moorestown laboratory showed that parasitism of oriental fruit moths by *quadridentata* in unsprayed apple was much greater than in peach twigs. *A. quadridentata* was reared from 43 percent of all samples of apples containing this host, and the average parasitization by this species in such collections was 12.9 percent, which was only slightly less than the 15.3 percent of *C. pomonella* in the same samples. *A. quadridentata* occurred through the entire range of this survey. It was a common parasite of *C. pomonella* in Alexander, Wilkes, and Surry Counties, N.C., south of its previously reported range.

In 1931 and 1932 over 56,000 *quadridentata* adults were propagated at the Moorestown laboratory on the oriental fruit moth (Allen et al. *1940*). Subsequently similar mass breeding was accomplished in New York, Connecticut, Ontario, and other places.

Phanerotoma fasciata Provancher

(Fig. 6)

The adult of *Phanerotoma fasciata* is yellowish and moderately robust, with an ovate abdomen having three visible tergites (fig. 6, *B*). Each wing (fig. 6, *A*) has two faint, smoky transverse bands. In much

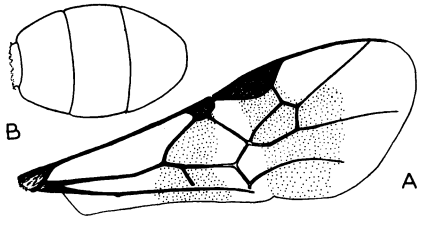

FIGURE 6.—*Phanerotoma fasciata: A*, Forewing; *B*, dorsal aspect of abdomen.

of the literature this species has been confused with *Phanerotoma tibialis* (Haldeman). Walley (*1951*) found that the *Phanerotoma* reared from olethreutids was *fasciata* and distinct from *tibialis*, which parasitizes pyralids. Hamilton (*1890*) reared *fasciata* from *Laspeyresia caryana* (Fitch) in the hulls of hickory, and he observed that the parasite formed its cocoon within the cell of the host.

Muesebeck et al. (*1951*) and Krombein et al. (*1958*) listed seven hosts, all of which are crop pests of the family Olethreutidae. These authors stated that the parasite occurs from Ontario south to Florida and west to British Columbia, Washington, Oregon, and Texas. It has been most commonly reared as a parasite of the oriental fruit moth, *Carpocapsa pomonella*, and *L. caryana*. Dozier et al. (*1929*) observed that in *C. pomonella* the parasite attacks the egg and issues from the cocooned host larva. Its life history has apparently not been worked out in detail, but it is similar to that of *Phanerotoma grapholithae* Muesebeck and *Ascogaster quadridentata*, both of which have been propagated in large numbers.

As a parasite of the oriental fruit moth, it has been recorded from New Jersey (Stearns *1927*, *1928*, Haeussler *1930*), New York (Daniel *1932*), Maryland (McConnell *1932*), and Delaware (Stearns and Amos *1941*). Haeussler found it a negligible parasite of the oriental fruit moth in peach twigs in New Jersey from 1925 to 1928, but it was the most abundant parasite overwintering in this host from quince fruit from 1928 to 1929.

The rearing at the Moorestown laboratory showed that *fasciata* was an unimportant parasite of the oriental fruit moth. Although more than one adult was reared from each of several collections of

infested peach twigs, the parasitism was never high. A total of 33 parasites were reared from 24 collections, 22 properties, 18 localities, and 16 counties. Approximately half of the total were reared from South Carolina and Virginia, two of the seven States from which *fasciata* was recovered. As a parasite of the oriental fruit moth in peach twigs, it was reared only east of the Alleghenies from southern New Jersey to South Carolina and on the southern shores of Lakes Ontario and Erie.

In the survey of fruitworms in unsprayed apple from 1952 to 1957, *fasciata* was recovered in only four counties of southern New Jersey, where the infestations of both the oriental fruit moth and *C. pomonella* were high. In that restricted area *fasciata* was recovered from 21 percent of the 77 collections from which the oriental fruit moth was reared and 28 percent of the 54 from which *C. pomonella* was reared. In the collections from which *fasciata* was reared it attained an average parasitization of 14.1 percent of the 750 oriental fruit moths and 5.6 percent of the 1,229 *C. pomonella* specimens reared.

Genus BRACON

The genus *Bracon* has a large number of species. *Bracon hebetor* Say is readily propagated on several easily reared grain insects, and it has been extensively used in biology and genetics studies.

Three species of *Bracon* have been reported as parasites of the oriental fruit moth. If their habits in that host are similar to those observed in other hosts, the method of rearing parasites at the Moorestown laboratory might fail to discover them. Most of the parasite records there were obtained on larvae that were collected in peach twigs, and these larvae transferred to other food or to cocoon strips before succumbing to parasites. In some *Bracon* species the larvae are paralyzed at the time the egg is deposited, and they are unable to make such transfers.

Bracon mellitor Say

(Fig. 7)

Bracon mellitor is one of the few parasites of the oriental fruit moth in which the adult parasite is robust and ferruginous. The abdomen is ovate with seven tergites. In the forewing (fig. 7) the second cubital cell is a conspicuously elongate parallelogram. This parasite was described more than 120 years ago.

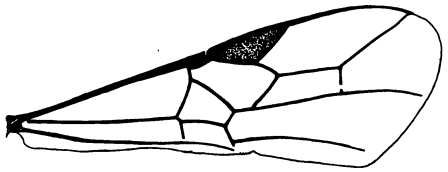

FIGURE 7.—Forewing of *Bracon mellitor*.

It has been known since 1905 as an important parasite of *Anthonomus grandis* Boheman (Hunter and Hinds *1905*). Since 1900 it has been recorded as a parasite of a considerable number of curculionid and lepidopterous hosts, including several important crop pests. Of these hosts, Muesebeck (*1925*), Muesebeck et al. (*1951*), and Krombein et al. (*1958*) recognized 10 curculionids and 8 Lepidoptera. The latter includes three olethreutids, two gelechiids, and one each of the families Phalaenidae, Phycitidae, and Momphidae. So far as is known the larvae of all these hosts are well protected within plant tissues. These authors gave the distribution of this species as the Atlantic Coastal States from Massachusetts southward, west to South Dakota and Texas, and in Mexico and Hawaii.

Several biological studies have been made of *mellitor*, including those on *Pectinophora gossypiella* (Saunders) by Willard (*1927*) in Hawaii and studies on *A. grandis* by Fenton and Dunham (*1929*) in South Carolina, Miller and Crisfield (*1930*) in Georgia, and Folsom (*1936*) in Louisiana. They observed that the parasite attacked larvae that were full grown or nearly so.

Folsom found that the ovipositing female was attracted by the larva itself, but only when it was enclosed in a cell that might be either natural or artificial. Usually only one or two eggs were laid daily, and generally only one to each host. In midsummer the preovipositional period was about 24 hours, and ovipositing females lived about 2 weeks. In cooler weather males lived as long as 40 days and females 70. Unfed adults survived for less than a week. Folsom observed that females drilled through soft spots in cotton squares to oviposit, but others stated that oviposition occurred through cuts or holes made by the host. The larva was permanently paralyzed, and an egg was laid on or near it in the cell of the host. Several observed that the larva fed externally on host larvae. Usually one adult emerged from a single host. Folsom found that in August the egg hatched in about 24 hours, the larva completed feeding in 3 days, and the normal cycle from oviposition to adult was 12 days. The white cocoons were formed within the cell of the host. Folsom noted that when the adult emerged from cotton squares, it chewed off the end of the cocoon and gnawed an exit hole through the wall of the square. Both Willard and Fenton found that unfertilized females produced only males. Females mated with parthenogenic males produced normal offspring.

Noble and Hunt (*1942*) had moderate success in propagating *mellitor* by exposing larvae of the laboratory host *Ephestia kuehniella* Zeller, which were confined between cloth and paper layers in embroidery hoops. They also reared the parasite less successfully on larvae artificially paralyzed in hot water.

B. mellitor has been recorded as a parasite of the oriental fruit moth in Ontario (Smith *1929*), South Carolina (Eddy and Nettles *1931*), Maryland (McConnell *1932*), Tennessee (Butler *1933*), and Michigan (Merritt *1933b*). Smith reared it from infested peach fruits and Butler from infested peach twigs.

In the work at the Moorestown laboratory *mellitor* was reared from the oriental fruit moth only a few times and was never an important parasite. It was reared from the following counties: Burlington, N.J., Greenville and Spartanburg, S.C., Delaware and Knox, Ind., and Richland, Ill. Usually it was reared from oriental fruit moths infesting peach twigs, but once it parasitized a larva after the cocoon had been formed.

Bracon gelechiae Ashmead

Muesebeck et al. (*1951*) and Krombein et al. (*1958*) gave the distribution of *Bracon gelechiae* as all the United States and Canada, Mexico, Bermuda, and India. They listed 24 hosts, all of which are small or moderate-sized Lepidoptera that are chiefly stem or fruit borers, bud moths, casebearers, or leaf rollers. They include seven olethreutids, six gelechiids, three tortricids, two pyraustids, and one

each in the families Heliodinidae, Phycitidae, Phalaenidae, Oecophoridae, and Coleophoridae.

Poos (*1928*) studied the biology of *gelechiae*, which originated from *Gnorimoshema operculella*, in the laboratory host *Diatraea zeacolella* Dyar. In this host the parasite was gregarious, and as many as 20 adults were reared from one larva. The period from egg deposition to emergence of adults ranged from 10 to 12 days. The eggs hatched in 28 hours. One female deposited 62 eggs. Under favorable conditions females lived on an average for 16.8 days and males for 6.6 days. Unfertilized females produced males only. The habit of many hymenopterous adults of feeding on the juices of the host was first noted in 1921 by Trouvelot in *gelechiae* (*in* Clausen *1940*).

B. gelechiae has been reported as an occasional parasite of the oriental fruit moth in Virginia (Stearns *1919*), New Jersey (Stearns *1928*, Haeussler *1930*), Maryland (McConnell *1932*), Michigan (Merritt *1933b*), and Delaware (Haden *1935*). It was not reared at the Moorestown laboratory from this host after 1930.

Bracon politiventris (Cushman)

The distribution of *Bracon politiventris*, as reported by Muesebeck et al. (*1951*) and Krombein et al. (*1958*), is from Nova Scotia to Virginia, west to British Columbia, Oregon, and Colorado, and in Louisiana. Their list of hosts includes eight Lepidoptera whose larvae are leaf rollers, bud moths, and fruit or stem borers. Five are tortricids and three are oletheutids. Daviault (*1935*) reared *politiventris* from an oecophorid, *Psilocorsis* sp., feeding on birch.

This parasite was reported to feed externally on the larvae of *Archips rosaceanus* (Harris) (Schuh and Mote *1948*) and of *Choristoneura fumiferana* (Dowden et al. *1948*), which it destroys. Muesebeck (*1925*) and Dowden et al. (*1950*) noted that it was gregarious. Muesebeck[4] stated that in the U.S. National Museum collection there are two specimens reared from the oriental fruit moth, one collected from Salisbury, Md., in 1939 and one from Lorain County, Ohio, in 1933. It was never reared from this host at the Moorestown laboratory.

[4] Personal communication dated 1956.

Ichneumonidae

The ichneumonid parasites of the oriental fruit moth include several genera that attack only developing larvae and other genera that are parasitic only on the cocoon stage. Insofar as is known all the larval parasites develop internally from eggs laid within the bodies of the hosts. In general they issue from larvae after they have cocooned, and they form their cocoons beside the host remains. The Ichneumonidae differ from the Braconidae in having the third discoidal cell separated from the second apical cell and the first discoidal cell confluent with the first cubital cell (fig. 8).

KEY TO GENERA OF ICHNEUMONIDAE ATTACKING ORIENTAL FRUIT MOTH LARVAE

1. First segment of abdomen stalked, usually more than twice as long as basal width 2
   First segment of abdomen not stalked, usually not more than twice as long as basal width ..... *Glypta, Toxophoroides*
2. Areolet not present 3
   Areolet present and closed before junction with radius ..... *Campoplex*
3. Hindfemur without strong spine before its apex 4
   Hindfemur with conspicuous spine ventrally and before apex ..... *Pristomerus*
4. Stigma very narrow, much more so than length of intercubital vein 6
   Stigma wider than length of intercubital vein 5
5. Clypeus with suture or depression between it and face; last four segments of abdomen strongly compressed; ovipositor straight and nearly as long as abdomen ..... *Temelucha*
   Clypeus fused with face; last four abdominal segments not strongly compressed; ovipositor short and abruptly upcurved at tip ..... *Horogenes*
6. Antennae much shorter than body; eyes margined behind with yellowish white ..... *Atrometus*
   Antennae nearly or quite as long as body; eyes broadly margined behind with red ..... *Labrorychus*

Glypta rufiscutellaris Cresson

(Figs. 8 and 9)

Glypta rufiscutellaris adults are large and black, with the abdomen broadly joined to the thorax. The wing venation is shown in figure 8. The distribution of *rufiscutellaris* is given by Townes (*in* Muesebeck et al. (*1951*)) as the Transitional and Upper Austral Zones from the Atlantic Ocean to Alberta and Utah. It is preeminently a parasite of olethreutids; it was reared from 11 species of this family. One tortricid is also listed as a host. *G. rufiscutellaris* seems not to have been noted as a parasite of the oriental fruit moth until 1926 (Garman *1926*).

Since the wide fluctuations in abundance as a parasite of the oriental fruit moth are probably linked to its abundance in alternate hosts commonly present in or near peach orchards, considerable

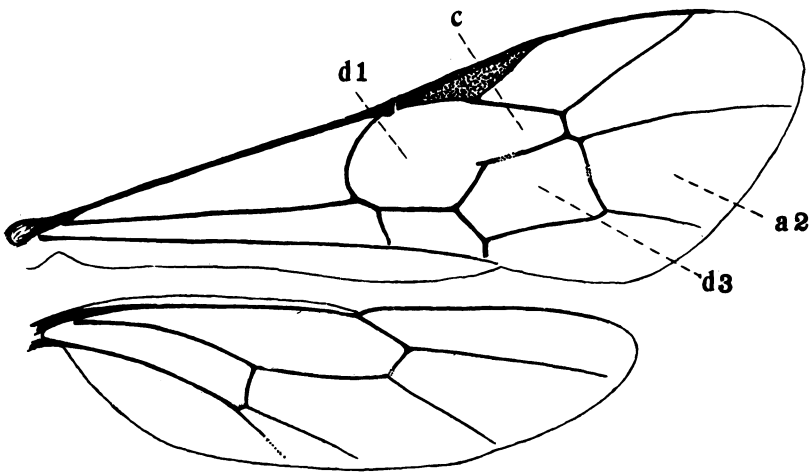

FIGURE 8.—Wings of *Glypta rufiscutellaris*, showing first discoidal cell (*d* 1), first cubital cell (*c*), third discoidal cell (*d* 3), and second apical cell (*a* 2).

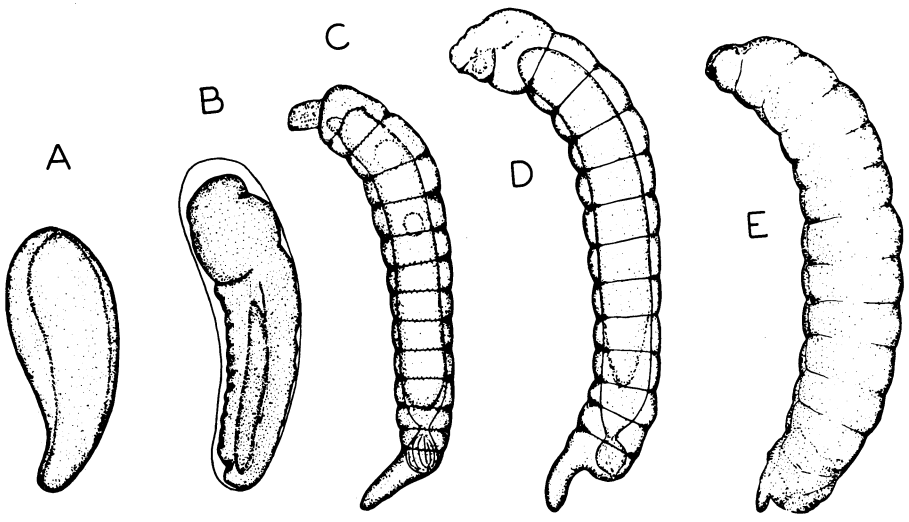

FIGURE 9.—Eggs and larvae of *Glypta rufiscutellaris: A*, Uterine egg; *B*, egg from host 2 days after deposition; *C*, first-instar larva; *D*, second-instar larva; *E*, third-instar larva. (Adapted from Montgomery (*1935*).)

attention has been given to such hosts. Allen and Lott (*1930*) found that it was a common parasite of *Epiblema strenuana* in New Jersey, Pennsylvania, Ohio, and Indiana. Its occurrence in that host has subsequently been studied by Crawford (*1933*) in western New York, Montgomery (*1933*) in Indiana, and Haden (*1935*) and Rice (*1935*) in Delaware. Its parasitism of *E. strenuana* has also been noted in Maryland (McConnell *1932*), Virginia (Bobb *1942*), Connecticut (Schread et al. *1942*), Ohio (Blackburn *1944*, *1948*), and Ontario (Putnam *1935a*, Boyce and Dustan *1954*).

Putnam also found that it parasitized a common hawthorn leaf tier in considerable numbers. This was subsequently identified as *Epinotia laracana* (Kearfott) (?) (Putnam *1938*). He also reared *rufiscutellaris* in Ontario less commonly from *Argyrotoxa semipurpurana* Kearfott, *Grapholitha packardii* Zeller, *G. prunivora*, *Laspeyresia caryana*, *Epiblema scudderiana*, and *E. obfuscana* Dyar in goldenrod and from *Melissopus latiferreanus* in acorns. Dohanian (*1942*) also reared it from *M. latiferreanus* in California, Oregon, and Washington. Jaynes and Marucci (*1947*) reared very small numbers from *Carpocapsa pomonella* in West Virginia. Although it appears in some host lists as a parasite of *Ancylis comptana fragariae*, this is probably an error. The author has no record of its being reared in that host and failed to rear it in that host at the Moorestown laboratory.

The chief life-history studies of *rufiscutellaris* were made by Crawford (*1933*), Montgomery (*1935*), and Rice (*1935*). Crawford reared it from the oriental fruit moth in western New York. The female was relatively inactive in midday. Oviposition was accomplished in a few seconds. The parasite inserted the ovipositor in the hole left by the twig-infesting host larva. Sometimes oviposition on the same larva was repeated before the female left it. Females often attacked free-crawling larvae and oviposited in

them. Only once was a female observed feeding on larval juices. The preoviposition period was 2 to 6 days. When the adults were maintained on sugar and water, the average longevity was 26 days for females and 16½ days for males. The parasite attacked any stage of oriental fruit moth larvae, but few *rufiscutellaris* insects matured when newly hatched or when nearly mature larvae were exposed.

The egg (fig. 9, *A*, *B*) was typically that of an ichneumonid. It was slightly curved, clavate, about 0.3 mm. long, and fully three times as long as wide. It was always free in the body cavity and was oriented with the body and close to the midgut. Apparently only one egg was laid at each oviposition. The egg in midsummer hatched in about 40 hours.

According to Crawford there were four larval instars, but Montgomery found only three. These were characterized by a conspicuous anal process, which became less prominent in each succeeding instar (fig. 9, *C*, *D*, *E*). The developmental period was synchronized to that of the host. The mature larva cast off the completely emptied skin of the host after the latter had cocooned. It spun a thin white cocoon beside the host remains. In western New York *rufiscutellaris* overwintered as a full-grown larva within its cocoon, transforming to a prepupa in late winter. Peak pupation was on April 11, and emergence began early in May. The emergence of first-generation adults began early in July and of second-generation adults on August 8. Unmated females produced males only, and when these males were mated with females, their progeny were of both sexes.

Montgomery also studied *rufiscutellaris* by rearing it in the oriental fruit moth. His observations are in substantial agreement with those of Crawford. However, he observed that the period from oviposition to hatching was 6 days. He also obtained his highest rates of parasitization (80 percent) when larvae only 1 day old were exposed to ovipositing females.

Rice collected adults in the field. He found them fairly common in the spring up to May 14 and not again until July 1. Males were observed feeding on the flowers of wild turnip (*Brassica campestris*), cherry (*Prunus*), and Norway maple (*Acer platanoides*). He kept adults that emerged from overwintering *E. strenuana* in humid cages and fed them sugar and water. The average longevity of females was 49.4 days.

Haeussler (*1930*) observed that in 1928 only 2.9 percent of the parasites reared from peach twigs collected in New Jersey were parasitized by *rufiscutellaris*, but 25 percent of the parasites that were reared from the oriental fruit moth and that overwintered after issuing from quince were this species. This showed the ability of the parasite to attack larvae that feed on fruit.

Over the northern part of the range of the oriental fruit moth, *rufiscutellaris* is one of the three most important parasites of the larvae of this host. Rates of parasitization in excess of 80 percent have been observed, but the average has been far below that of *Macrocentrus ancylivorus* when both species occurred in the same locality. Numerous observers have noted that there is little or no parasitism of the first generation by *Glypta* and that the parasite is much more prevalent in some seasons than others. It has not been found as an important parasite of any other crop pest.

The occurrence of *rufiscutellaris* as a parasite of the oriental fruit moth has been recorded for Connecticut (Garman *1926*, *1929*, *1930a*,

1940, Schread et al. *1942*), New Jersey (Stearns *1927*, Driggers *1929*, *1930a*, *1940*, *1941*, *1944*, Haeussler *1930*, Brunson *1940*), Maryland (McConnell *1928*, *1932*, *1934*), Ontario (Smith *1929*, Steenburgh *1930a*, *1931*, Van Steenburgh *1932*, *1935*, *1936*, Van Steenburgh and Boyce *1938*, Putnam *1935a*, Boyce *1947a*, *1949*, Boyce and Dustan *1954*), Pennsylvania (Stear *1929*), Ohio (Stearns and Neiswander *1929*, *1930*, Neiswander and Vogel *1933*, Blackburn *1944*, *1948*, Weaver *1949*), New York (Daniel *1930*, *1932*, Crawford *1933*, Daniel et al. *1933*, Wheeler *1945*), Tennessee (Butler *1932*, *1933*), Michigan (Merritt *1933a*, *1933b*), Delaware (Haden *1935*, Stearns and Amos *1941*), Virginia (Bobb *1939*, *1942*), and Missouri (Wingo *1940*, *1941*).

The distribution of *rufiscutellaris* as a parasite of the oriental fruit moth is very irregular. Even within the borders of a State or Province there are large differences between sections. Driggers (*1944*), who compared the parasitism in the hilly orchards of northern New Jersey with the parasitism in the orchards on the Coastal Plain of southern New Jersey for many years, found that *rufiscutellaris* was consistently more abundant in the hilly orchards from 1930 to 1944. In Ohio Stearns and Neiswander (*1930*) found it more abundant in the northern part of the State. In Ontario Steenburgh and later workers found it persistently more abundant in some districts than others. Similar observations have been made by McConnell (*1932*) in Maryland and Bobb (*1939*) in Virgina. In sections where it is abundant there has been practically no parasitism of the first generation. Steenburgh in Ontario, Stearns and Neiswander in Ohio, and others observed that its abundance as a parasite of the oriental fruit moth varies greatly from season to season.

Several workers investigated the fact that *rufiscutellaris* is an important parasite of the second generation of the oriental fruit moth in districts where it is scarce or absent in the first generation. They showed that over a large part of the area infested by this host, large numbers of *rufiscutellaris* overwinter successfully in *E. strenuana*, which is abundant in and around peach orchards and is relatively free of predator and parasite attack. These parasites start to emerge about 3 weeks before first-generation larvae of the oriental fruit moth are available, and emergence may indeed be completed several days beforehand.

However, Crawford (*1933*) maintained *rufiscutellaris* adults, which emerged early, until long after first-generation oriental fruit moth larvae became available and obtained parasitism of this host from June 5 to 22. He did not state the source of the adults used in the tests. This finding showed that the lack of parasitism of first-generation oriental fruit moths could not be due to inability of early emerging *Glypta* adults to survive until young fruitworms were available.

Rice (*1935*) was even able to maintain early emerging *rufiscutellaris* specimens obtained from *E. strenuana* until the first summer brood of *E. strenuana* became available on June 28 and to obtain parasitism of it. However, all the long-lived females died within a week of June 28, and they were obviously not responsible for the long-continued parasitism of *E. strenuana*, such as occurs during the summer brood.

The evidence available indicates that the large population of *rufiscutellaris* emerging in early spring from overwintering *E. strenuana* must be strongly attracted to some

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alternate host or hosts other than the oriental fruit moth and that the progeny of this generation must be largely responsible for the high rates of parasitism in the second generation of the oriental fruit moth and the first generation of *E. strenuana*. Whether the host or hosts that produce the large July populations of adults are among those listed has not yet been determined. It seems to have been presumed that the *rufiscutellaris* reared from *E. strenuana* is biologically identical to that reared from the oriental fruit moth. However, no statement has been found showing that this has been confirmed by crossbreeding or crosstransfer of hosts.

Several workers have propagated *rufiscutellaris* by exposing young oriental fruit moth larvae to ovipositing females. Allen et al. (*1940*) obtained over 4,000 early emerging adults from ragweed and considered this the best source of the parasite when emergence can be retarded by cool storage. They colonized at several points where the parasite was not known to occur without obtaining favorable results. Shipments of the parasite originating at the Moorestown laboratory have been sent to Japan (Ishii *1940*), Australia (Anonymous *1936*), and Italy (Grandi *1937*), but so far as is known it has not become established in those countries. Boyce and Dustan (*1954*) found that although *rufiscutellaris* continues to be a common parasite of *E. strenuana*, it has sharply decreased in its parasitism of the oriental fruit moth in peach in Ontario during the 6 years that DDT and other organic insecticides have been used.

In the recovery work at the Moorestown laboratory 10,501 *rufiscutellaris* specimens were reared (table 3). When the entire infested area is considered, *rufiscutellaris* was about equal in importance to *Macrocentrus delicatus*, and it was the second or third most abundant larval parasite of the oriental fruit moth. It was especially important in Massachusetts, Connecticut, New York, Pennsylvania, West Virginia, Ohio, and Michigan. In New Jersey, Maryland, and Virginia *rufiscutellaris* was an important parasite in the hilly sections but almost absent from this host in the Coastal Plain orchards. It was relatively unimportant as a parasite of this host in Rhode Island, Delaware, Indiana, Illinois, Kentucky, Tennessee, Missouri, and Arkansas. Although it was recovered in small numbers immediately after liberation in South Carolina and Georgia, no evidence was obtained at the Moorestown laboratory that it occurs normally as a parasite of the oriental fruit moth in the peach-growing districts of North Carolina, South Carolina, and Georgia.

From 1930 to 1932 *rufiscutellaris* was reared from *E. strenuana* in both generations at the Moorestown laboratory and from the first generation in collections taken at Cinnaminson, N.J., Cheswold, Del., Berlin, Md., Chambersburg, Coatesville, Gettysburg, Greensburg, Ligonier, and York, Pa., Eldorado, Md., Springfield, Ohio, and Greenfield, Indianapolis, and Richmond, Ind.

Toxophoroides albomarginatus albomarginatus (Cresson)

The ichneumonid *Toxophoroides albomarginatus* is distributed from Maine and Manitoba south to North Carolina and Arkansas (Muesebeck et al. *1951*). It belongs to a group that are internal parasites of Lepidoptera. It has been reported as a parasite of four species—one each in the families Gelechiidae, Tortricidae, Olethreutidae, and Phycitidae.

It is a rare parasite of the oriental fruit moth. At the Moorestown

laboratory only one specimen was reared from this host. It emerged from a collection of infested peach twigs taken at Pullman, Mich., on July 31, 1937. It was identified by R. A. Cushman at the U.S. National Museum, and the host was verified by a microscopic examination of the remains.

Genus CAMPOPLEX

Several species of *Campoplex* are occasionally reared from the oriental fruit moth, but only one has been named. The parasites attack larvae in twigs and form their cocoons within the host cocoon. The adults of this genus are easily distinguished from all others reared from this host by the presence of an areolet, which is closed at or before its juncture with the radius.

Campoplex tortricidis Cushman

Cushman (*1915*) described *Campoplex tortricidis* in 1915 from parasites reared in Pennsylvania from *Paralobesia viteana*. It has since been recorded from only one additional host, the oriental fruit moth (Neiswander *1936*).

In the survey work at the Moorestown laboratory *tortricidis* was reared only once as a parasite of the oriental fruit moth. It was obtained from peach twigs collected at Clemson, S.C., on June 13, 1932. The host remains were examined, and the adult was determined by R. A. Cushman at the U.S. National Museum. The cocoon was translucent white, with a faint opaque-white equatorial band.

Campoplex Spp.

Other species of *Campoplex* were reared occasionally at the Moorestown laboratory as parasites of the oriental fruit moth. All were obtained from collections of infested peach twigs, out of which this insect was the only host to emerge, but there was no identification of host remains except for one specimen reared in 1933. One *Campoplex* species is represented by four specimens—Oriental Fruit Moth Investigations Nos. 2911, 2989, 3108, and 3146—from East Williamson, N.Y., Lawrenceville, N.J., and Columbus and Waterville, Ohio, respectively. Another species is represented by three specimens—Oriental Fruit Moth Investigations Nos. 2877, 3001, and 3002—from Commerce, Ga., and York, S.C. Specimen No. 2880 from Bremen, Ga., is possibly the same species. A third species is represented by one specimen—Oriental Fruit Moth Investigations No. 2919—from Centralia, Ill. All these *Campoplex* species were reared in 1938, but several unidentified *Campoplex* species were also reared from the oriental fruit moth in 1933 and 1945.

Genus HOROGENES

Three American *Horogenes* species have been reared from the oriental fruit moth. None of these are important parasites of this host, although *Horogenes obliteratus* (Cresson) is common. The *Horogenes* adults are moderate sized and mostly black. They are readily recognized by the short, sickle-shaped, up-curved ovipositor of the female. The wing venation resembles that of *obliteratus* (fig. 10).

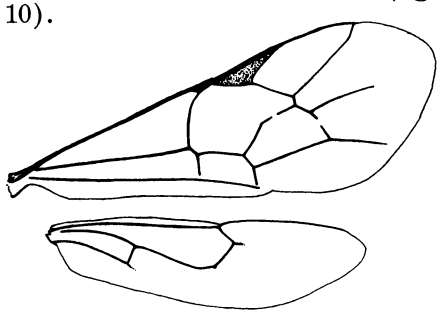

FIGURE 10.—Wings of *Horogenes obliteratus*.

Horogenes obliteratus (Cresson)

(Fig. 10)

Horogenes obliteratus has been known by several names since it was described by Cresson nearly a hundred years ago. The first recorded host was *Acleris minuta* (Robinson) (Weed *1887*), from which it was reared in Illinois 23 years after it was originally described. It is best known as the most common larval parasite of *Paralobesia viteana*, in which it was first reported by Slingerland (*1904*) from western New York and subsequently by numerous other workers in New York, Pennsylvania, Ohio, Michigan, and Delaware.

Townes (*1945*) listed 14 hosts, all Lepidoptera, of which 3 belong to each of the families Gelechiidae, Tortricidae, and Olethreutidae, 2 to the Yponomeutidae, and one each to the families Coleophoridae, Glyphipterygidae, and Pyraustidae. The hosts are small worms, which live mostly concealed as twig borers, leaf rollers, casebearers, and fireworms. Several are crop pests. The distribution as given by Townes is from Ontario, Massachusetts, Virginia, and Tennessee to Michigan, Iowa, and Missouri.

Very little has been published regarding the biology of *obliteratus*. Porter and Garman (*1923*) stated that in *Anthophila pariana* (Clerck) it oviposits in larvae two-thirds to full grown and emerges from the cocoon. Gleissner (*1943*) reported it as abundant in the first generation of *P. viteana* near Lake Erie, but he never found it in the overwintering generation. Blackburn (*1946*) observed that unlike most larval parasites of the oriental fruit moth it frequently cocooned in moist twigs or even in tunnels in the fruit of collected material, from which insects were being reared. Boyce and Dustan (*1954*) found that since spraying with DDT and parathion has become a general practice, *obliteratus* is less abundant as a parasite of the oriental fruit moth in the peach-growing districts of Ontario.

The first record of *obliteratus* occurring as a parasite of this host was in 1928 (Leonard et al. *1928*). Subsequently it has been reported from this host in New Jersey (Driggers *1929*, Haeussler *1930*), Ontario (Smith *1929*, Steenburgh *1931*, Boyce *1947a*), Ohio (Stearns and Neiswander *1930*, Weaver *1949*), New York (Daniel *1932*), Michigan (Merritt *1933b*), and Pennsylvania and Delaware (Stearns and Amos *1941*). It has been reared as a parasite of oriental fruit moth larvae attacking peach twigs. Boyce in a survey from 1929 to 1946 found that in the Niagara district of Ontario it parasitized up to 9.5 percent of the first-generation and 2.1 percent of the second-generation larvae. In southwest Ontario it was frequently the most important parasite in the first generation, particularly from 1938 to 1941, with averages up to 18.0 percent. Here also, rates in the second generation were lower and never above 4.0 percent.

In the survey work at the Moorestown laboratory *obliteratus* was found to be a larval parasite of the oriental fruit moth in 12 States, but nowhere as an important parasite (table 3). *H. obliteratus* was most abundant in the following counties: Wayne and Orleans, N.Y., Ottawa, Ohio, Ingham, Mich., and Elkhart and Lawrence, Ind. In several of these counties there are extensive vineyards in which *obliteratus* is also a common parasite of *P. viteana*. From several States where extensive surveys were made, including Delaware, North Carolina, South Carolina, Georgia, Tennessee, and Missouri, *obliteratus*

was not recovered, and it was uncommon in Massachusetts, Connecticut, New Jersey, Maryland, and Kentucky.

Horogenes rosanae (Viereck)

Horogenes rosanae was described in 1924 from one female reared from *Archips rosana* (Linnaeus) (Viereck *1924*). It has been found only in Nova Scotia, New York, Ontario, and Saskatchewan (Townes *in* Muesebeck et al. (*1951*)). Daniel (*1932*) reported that in Niagara County, N.Y., from 1929 through 1931 four individuals were reared as larval parasites of the oriental fruit moth. Host remains were not identified, but it seems improbable that the host of all four could have been any other insect than the oriental fruit moth. No other published records regarding the hosts of this parasite have been found.

Genus PRISTOMERUS

The three species of *Pristomerus* known to be parasitic on the oriental fruit moth are internal parasites of the larvae. One of these species—the Eurasian *P. vulnerator* (Panzer)—was colonized in North America several times. These species issue after the host has cocooned and spin their cocoons beside the host remains. At least three species—*P. austrinus* Townes & Townes, *P. euryptychiae* Ashmead (fig. 11), and *P. vulnerator*, which was studied in Europe by Rosenberg (*1934*) in *Carpocapsa pomonella*—have darkly pigmented eggs easily located in the lightly colored host tissues. The first-instar larva has a whiplike caudal segment, which makes it prominently vermiform. The wing venation resembles that shown in figure 11. The head and thorax are mostly red in the adults of *P. austrinus* and *P. euryptychiae*.

KEY TO SPECIES OF PRISTOMERUS ATTACKING ORIENTAL FRUIT MOTH LARVAE

(Adapted from Cushman (*1920*))

1. Eye fully third longer than wide; ocelli large, lateral ones in female closer together than their greatest diameter, in male touching eyes; malar space barely half as long as basal width of mandible ..... *euryptychiae* Ashm.
   Eye barely fourth longer than wide; ocelli smaller, lateral ones in female removed from each other by their diameter, in male distinctly removed from eyes; malar space much more than half as long as basal width of mandible ..... *austrinus* T. & T.

Pristomerus euryptychiae Ashmead

(Fig. 11)

Pristomerus euryptychiae adults have a wing venation (fig. 11, *A*) resembling that of their close relatives in the genera *Pristomerus* and *Temelucha*, but the bodies are more robust than in *Temelucha* and they also differ conspicuously in having a large stout tooth near the middle of the hindfemur (fig. 11, *B*). The first-instar larva (fig. 11, *E*) has a long pigmented head and an extremely long caudal segment. It hatches from a black egg deposited within the body of the host larva. It leaves a subconical eggshell (fig. 11, *D*), usually found without the anterior cap and by which it can be identified in dissected larvae. The cocoon, formed beside the host larval remains, is dull white to faintly tawny, sometimes with a faint medial white band. Its sides are parallel, and on emergence the whole anterior end is roughly chewed away.

P. euryptychiae is distributed from the Atlantic Ocean to 100° W.

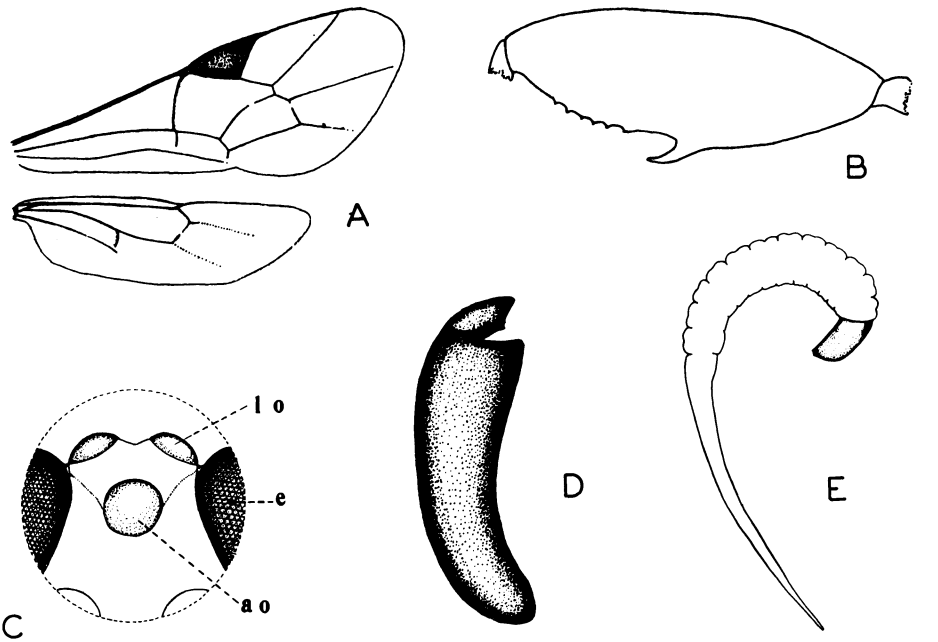

FIGURE 11.—*Pristomerus euryptychiae: A*, Wings; *B*, femur of hindleg; *C*, section of head with enlarged ocelli, showing lateral ocellus (*l o*), anterior ocellus (*a o*), and eye (*e*); *D*, eggshell; *E*, first-instar larva.

in the Upper and Lower Austral Zones (Townes *in* Muesebeck et al. (*1951*)). Townes (*1945*) listed four hosts, to which he added five in 1951. Other recorded hosts are *Gnorimoschema gallaesolidaginis*, and *Polychrosis carduana* Busck (Blackburn *1944*), *Walshia amorphella* (Brett *1946*), *Suleima helianthana* (Satterthwait *1948*), and *Acrobasis caryae* (Nickels et al. *1950*). Most of these are olethreutids, three are phycitids, and one each belongs to the families Gelechiidae and Momphidae. These hosts are chiefly crop pests. They are all small lepidopterous larvae, such as stem borers, fruitworms, casebearers, seed-head feeders, or leaf rollers, which live in protected environments.

This insect has been reported more frequently as a parasite of the oriental fruit moth than of any other host. It has been reared as a larval parasite of this host in New Jersey (Stearns *1927*, *1928*, Haeussler *1930*, Driggers *1930a*, *1930b*, *1932*, Brunson *1940*), Ohio (Stearns and Neiswander *1930*, Neiswander and Vogel *1933*, Blackburn *1944*, Weaver *1949*), New York (Daniel *1932*), Tennessee (Butler *1932*, *1933*), Maryland (McConnell *1932*, *1934*), Michigan (Merritt *1933b*), Delaware (Haden *1935*, Stearns and Amos *1941*), Ontario (Van Steenburgh *1935*), Virginia (Bobb *1939*), and Connecticut (Schread et al. *1942*). When quantitative data have been given, all authors show that *euryptychiae* is relatively unimportant as a parasite of the oriental fruit moth, although it usually appears among the six most abundant parasites of that host.

The extent to which *Epiblema strenuana* acts as a reservoir of this parasite in ragweed near peach orchards has been studied by several workers, including Allen and

Lott (*1930*) in New Jersey, Pennsylvania, and Ohio; Montgomery (*1933*) in Indiana; Pepper and Driggers (*1934*) in New Jersey; Haden (*1935*) in Delaware; and Neiswander (*1936*) in Ohio. It has been reared from overwintered oriental fruit moths (Haeussler *1930*, Driggers *1932*) and from overwintered *E. strenuana* (Pepper and Driggers *1934*, Haden *1935*, Allen et al. *1940*). Ishii (*1940*) stated that *euryptychiae*, which had been introduced into Japan as a parasite of the oriental fruit moth, had failed to become established.

In the survey of the oriental fruit moth parasites of infested peach twigs made at the Moorestown laboratory from 1931 to 1938, inclusive, *euryptychiae* was among the six most important parasites, its relative position varying from year to year between the fourth and seventh most abundant. It was recovered from 18 States, from which numerous samples were taken. It was distributed from Massachusetts to Georgia and west to Illinois and Missouri.

The average parasitization in collections in which *euryptychiae* occurred was 4.1 percent. However, the average was 8 percent or more in such collections from New York, Pennsylvania, and Ohio. Most of the highest rates of parasitism by this species were between 1931 and 1935 in the following counties: Rockland, N.Y., Mercer, N.J., Cuyahoga, Erie, Fairfield, Franklin, Lorain, Ross, and Wayne, Ohio, and Van Buren, Mich. Except for Mercer and Cuyahoga Counties, these high rates occurred before *Macrocentrus ancylivorus* had become the dominant parasite in these counties. In individual collections, rates in excess of 50 percent were occasionally observed. Usually the parasitism by *euryptychiae* was low in May, moderate in June, and higher in July and August, but in 1936 there was considerable parasitism by this species in May.

In 1931 several hundred adults of *euryptychiae* obtained from overwintering *E. strenuana* were released at locations in Georgia, Indiana, and Tennessee where this parasite had not previously been recovered (Allen et al. *1940*). Subsequently it was found that very small numbers were present in the Tennessee locality in 1930 before the liberations were made. During the three seasons following the releases, *euryptychiae* was more abundant at the Tennessee site than it had been before release. In 1933, 24 percent of one lot of oriental fruit moths collected at a liberation site were parasitized by this species.

Pristomerus austrinus Townes & Townes

Most of the literature on *Pristomerus austrinus* is under the name *Pristomerus agilis* (Cresson). Its first recorded host was *Acrobasis vaccinii* Riley (Franklin *1915*). In addition, Townes (*1945*) listed *Acrobasis caryivorella* Ragonot, *Carpocapsa pomonella*, *Epiblema scudderiana*, and the oriental fruit moth, and in 1951 he added *Gretchena bolliana* (Slingerland). Four of these hosts are olethreutids and two are phycitids. All are small Lepidoptera whose larvae are concealed as fruitworms, stem borers, or casebearers. Townes (*in* Muesebeck et al. (*1951*)) stated that *austrinus* is distributed from the Atlantic Ocean to 100° W. in the Upper and Lower Austral Zones and is also in Guatemala.

Franklin (*1950*) found it to be a common parasite of *A. vaccinii* in Massachusetts bogs, although not of much value since it competed with a species of *Phanerotoma*. From 1914 to 1916 the parasite was

more common on the "dry" than the winter-flooded bogs. The female oviposited through a hole made in the berry by *A. vaccinii*. The eggs were deposited in the larvae and were elongate, curved, and black. Usually one egg was deposited to a host, but as many as four were found. The parasite overwintered in the body of *A. vaccinii* and pupated during the first half of June. Butler (*1933*) reared 70 as parasites of the oriental fruit moth in Roane County, Tenn., from 1930 to 1932.

In the survey of oriental fruit moth parasites made at the Moorestown laboratory *austrinus* was relatively uncommon. A total of 18 specimens were reared as larval parasites of this host and were from the following localities: Bridgeboro, Evesboro, and Clarksboro, N.J., Lovingston, Va., DuPont, Ind., Tunnel Hill, Ill., Harriman and Kingston, Tenn., and Kimmswick, Illmo, Jefferson Barracks, and Jackson, Mo. Usually only single specimens were reared from a collection, but the parasitization by *austrinus* in the Tunnel Hill sample was 15 percent.

Genus TEMELUCHA

Six described North American species of *Temelucha* are parasites of the oriental fruit moth. Insofar as is known they are all solitary parasites of the larvae, which they probably attack when the larva is small and issue after it has spun its cocoon to form their cocoons beside the larval remains of the host. Each of these species has a limited number of hosts. *T. minor* (Cushman), *T. forbesi* (Weed), and *T. grapholithae* (Cushman) are abundant enough as parasites of the oriental fruit moth to be economically important at times, but the other three are only reared infrequently.

KEY TO SPECIES OF TEMELUCHA ATTACKING ORIENTAL FRUIT MOTH LARVAE

(Adapted from R. A. Cushman [5])

1. Males 7
   Females 2
2. Areola not or barely as long as petiolar area, apical carina not nearly continuous; lower parts of abdomen rarely conspicuously pale; hindfemur red; notaulices rarely conspicuously yellow 3
   Areola much longer than petiolar area, apical carina nearly continuous; lower part of abdomen beyond second segment conspicuously pale; hindfemur dark with a yellow streak above and another within; mesoscutum with median lobe black, lateral lobes red; notaulices conspicuously yellow ..... *grapholithae* (Cush.)
3. Abdomen stout, second segment not or barely four times as long as broad at base, compressed part (third segment to apex) not more than three times as long as deep 4
   Abdomen very slender, second segment distinctly more than four times as long as broad at base, compressed part much more than three times as long as deep ..... *forbesi* (Weed)
4. Eyes not distinctly divergent below 5
   Eyes distinctly divergent below ..... *carpocapsae* (Cush.)
5. Stigma less than half as broad as long; orbital ring complete or ground color of head reddish 6
   Stigma fully half as broad as long; yellow orbital ring broadly interrupted by black below and behind eyes ..... *cookii* (Weed)
6. Thorax predominantly black, sometimes more or less mahogany red ..... *epagoges* (Cush.)
   Thorax predominantly light reddish, sometimes more or less marked with yellow; head in front view broadly ovate, vertex distinctly arched, and

[5] Personal communication dated Dec. 20, 1932.

malar space much more than half as long as basal width of mandible; head predominantly reddish with orbital ring indistinct; ovipositor sheath about twice as long as first segment ..... *minor* (Cush.)

7. Areola not or barely as long as petiolar area 8
   Areola much longer than petiolar area, apical carina nearly continuous ..... *grapholithae* (Cush.)
8. Eyes and ocelli not conspicuously enlarged; malar space and space between eyes and ocelli not much reduced; eyes distinctly divergent below 9
   Eyes and ocelli very large; malar space and ocellocular space very much reduced; eyes parallel within 11
9. Yellow orbital ring complete; stigma less than half as broad as long 10
   Yellow orbital ring interrupted behind eyes; stigma more than half as broad as long ..... *cookii* (Weed)
10. Second abdominal segment less than four times as long as broad at base; malar space little more than half basal width of mandible ..... *carpocapsae* (Cush.)
    Second abdominal segment more than four times as long as broad at base; malar space nearly as long as basal width of mandible ..... *epagoges* (Cush.)
11. Second abdominal segment at least five times as long as broad at base ..... *forbesi* (Weed)
    Second abdominal segment not or barely four times as long as broad at base ..... *minor* (Cush.)

Temelucha minor (Cushman)

(Fig. 12)

The adult of *Temelucha minor* has a wing venation as shown in figure 12, *A*. The first-instar larva found free in the body cavity of the host larva has a long unpigmented head, an extremely elongate caudal segment, and paired ridges encircling each segment (fig. 12, *B*).

The hosts of *minor* listed by Townes (*1945*) include three olethreutids—the oriental fruit moth, *Epiblema strenuana*, and *Rhopobota naevana* (Hübner)—two gelechiids, including *Gnorimoschema axenopsis* (Meyrick), and a nolid—*Celama sorghiella* (Riley). It has also been recorded from *Isophrictis rudbeckiella* Bottimer in the flower heads of *Rudbeckia* (Bottimer *1926*), from *Carpocapsa pomonella* in Ontario (Boyce *1947b*), and rarely from *Pyrausta nubilalis* (Milliron *1953*, Blickenstaff et al. *1953*). Townes (*in* Muesebeck et al. (*1951*)) stated that it is distributed from the Atlantic Ocean to 100° W., mostly in the Upper Austral Zone.

The alternate host of *minor* that is most abundant near peach or-

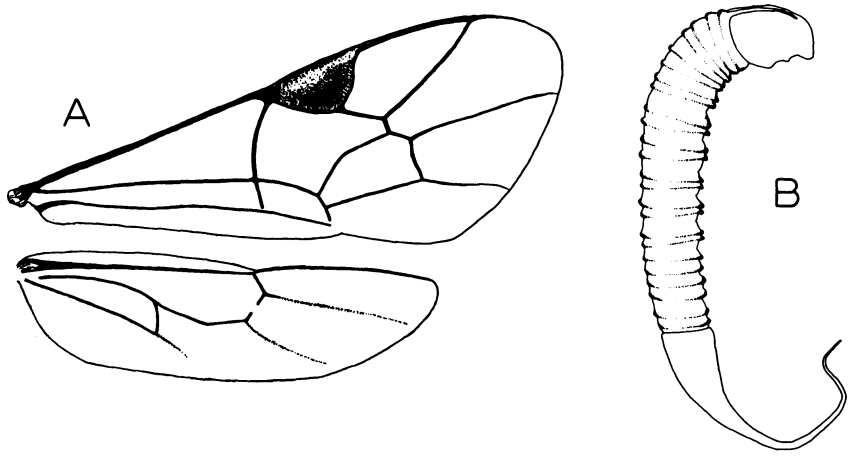

Figure 12.—*Temelucha minor: A*, Wings; *B*, first-instar larva.

chards is *E. strenuana*. *T. minor* has been reported from that host in New Jersey (Allen and Lott *1930*, Pepper and Driggers *1934*), Indiana (Montgomery *1933*), Ontario (Putnam *1935a*, *1938*), and Delaware (Haden *1935*). It was found to be moderately abundant as a parasite of *E. strenuana* in both summer and overwintering generations, but not so abundant in *E. strenuana* as in the oriental fruit moth.

T. minor has been much more frequently recorded from the oriental fruit moth than from any other host. It has been reared from this host in New Jersey (Stearns *1927*, *1928*, Haeussler *1930*, Driggers *1930b*), Ontario (Smith *1929*, Steenburgh *1930a*, *1931*, Van Steenburgh *1932*, *1935*, Van Steenburgh and Boyce *1938*, Boyce *1947b*, Boyce and Dustan *1954*), Ohio (Stearns and Neiswander *1930*, Neiswander and Vogel *1933*, Neiswander *1936*, Blackburn *1944*, Weaver *1949*), Tennessee (Butler *1932*, *1933*), New York (Daniel *1932*, Daniel et al. *1933*), Michigan (Merritt *1933a*, *1933b*), Delaware (Haden *1935*, Stearns and Amos *1941*), and Missouri (Wingo *1941*).

In Ontario where *minor* is more abundant than in most sections of the United States, Boyce (*1947b*) summarized its relative effectiveness against the oriental fruit moth from 1930 to 1946. Although he did not distinguish the several species of *Temelucha* in that area, *minor* was the only abundant species of the genus. In the Niagara district, *Temelucha*, chiefly *minor*, was the most common native parasite of the first generation during five seasons and generally the second most abundant during the second generation. On several occasions its average parasitization of oriental fruit moths for the season exceeded 10 percent, and in the second generation in 1931 its average was 29.3 percent. Weaver (*1949*) studied the parasitization by this species in Ohio for 16 years (1932–47), and he found it the fourth most important parasite, accounting for 5.8 percent of the 39,331 total parasites reared.

In the collections reared at the Moorestown laboratory *minor* was the fifth most abundant larval parasite of the oriental fruit moth (table 3). It was widely distributed from Connecticut to South Carolina and west to Illinois, Missouri, and Arkansas. The only States where it was absent and where a substantial number of oriental fruit moths were collected for rearing were Massachusetts, Georgia, and Tennessee. In collections where it occurred the average parasitization by *minor* was 5.8 percent. It was reared from collections taken in 84 counties. It was especially abundant in the following counties: Berrien and Van Buren, Mich., Monroe, Niagara, Orleans, and Wayne, N.Y., and Erie, Lorain, and Ottawa, Ohio. All are adjacent to the Great Lakes. In Ottawa County numerous collections had more than 20 percent of the total emergents parasitized by this species, and several exceeded 40 percent. It was abundant from early to late June.

Temelucha forbesi (Weed)

As now recognized, *Temelucha forbesi* includes the light-colored form referred to in the literature as *Temelucha tortricidis* (Cushman) (Walkley *in* Krombein et al. (*1958*)). The distribution of *forbesi* according to Townes (*1945*) is from Ontario and Maine to South Carolina and west to Michigan and Missouri. Leonard et al. (*1928*) stated that it was collected at the summit of Whiteface Mountain, N.Y., at nearly 5,000 feet.

T. forbesi has more known hosts than any other *Temelucha* species attacking the oriental fruit moth. Townes listed 10 hosts, including 4 olethreutids, 3 tortricids, 2 gelechiids, and 1 coleophorid. This group contains only small lepidopterous larvae that are sheltered in their normal habitat as fruitworms, stem borers, and leaf rollers. *T. forbesi* is not a common parasite of *Epiblema strenuana*, although it has been reported from it. Putnam (*1938*) reported rearing a single specimen from *E. strenuana* in Ontario, and in Connecticut it has only been reared from this host occasionally (Schread et al. *1942*). At the Moorestown laboratory it was never reared from that host. Haden (*1935*) who has reared *E. strenuana* extensively in Delaware and Bobb (*1942*) in Virginia never recovered *forbesi* from it.

T. forbesi has been more frequently reported from the oriental fruit moth than from any other host. It has been reared from that host in New Jersey (Stearns *1927*, *1928*, Haeussler *1930*, Driggers *1930b*), Ohio (Stearns and Neiswander *1930*, Neiswander *1936*), South Carolina (Eddy and Nettles *1931*), New York (Daniel *1932*), Ontario (Van Steenburgh *1932*, *1935*, Van Steenburgh and Boyce *1938*), Tennessee (Butler *1933*), Michigan (Merritt *1933b*), Delaware (Haden *1935*, Stearns and Amos *1941*), and Missouri (Wingo *1941*). From these reports it appears that *forbesi* is a widely distributed but relatively unimportant parasite of the oriental fruit moth.

In the rearing done at the Moorestown laboratory *forbesi* was recovered as a larval parasite of the oriental fruit moth in peach twigs from 17 States—from Massachusetts to South Carolina and west to Illinois, Missouri, and Tennessee. It was recovered from every State where substantial samples were taken, except Georgia. Although among the 11 most common larval parasites (table 3), it was relatively unimportant. In the 192 collections where *forbesi* was recovered, the 581 specimens reared were 2.8 percent of all emergents. The parasite was frequently more abundant in May and July than in June or August. In individual collections parasitization above 10 percent was uncommon.

Temelucha grapholithae (Cushman)

Although the adults of *Temelucha grapholithae* are conspicuously different from those of other *Temelucha* species attacking the oriental fruit moth, this species was not described until 1935. It has been reported only from Tennessee, Virginia, and Delaware (Cushman *1935*, Bobb *1939*, Stearns and Amos *1941*) and only as a parasite of this host. Over a 10-year period in Delaware, Stearns and Amos reared 117 specimens, which were 1.3 percent of the 9,241 parasites reared from this host.

From rearing work done at the Moorestown laboratory it appears that although not generally important, *grapholithae* was the only larval parasite, except *Macrocentrus ancylivorus*, that became more abundant and widely distributed as a parasite of the oriental fruit moth from 1930 to 1947. It was first found in that host at Sanford, N.C., in 1930, but despite very extensive survey work, only 15 specimens were reared by 1937. In the following year 36 were reared and in 1941, 587. The parasite was restricted to the southern part of the range of the oriental fruit moth and has not been recovered north of southern New Jersey, central Virginia, and southern Illinois. It was reared from 68 collections from 11 States from New Jersey to

Missouri and south to Georgia. Centers of abundance were in Sussex County, Del., where it was the second most important parasite in 1941, with parasitization rates in individual collections as high as 53 percent, and Spartanburg County S.C., where in individual collections parasitization from 1938 to 1944 ranged up to 41 percent. In the 68 collections from which *grapholithae* was reared, its average parasitization was 10.4 percent.

Temelucha epagoges (Cushman)

The distribution of *Temelucha epagoges* according to Muesebeck et al. (*1951*) is the Upper and Lower Austral Zones from the Atlantic Ocean to 100° W. They listed nine hosts, all small Lepidoptera and predominantly twig and stem borers. Five are olethreutids, two tortricids, and two momphids. In addition, Satterthwait and Swain (*1946*) reported rearing this parasite from two Lepidoptera, *Suleima helianthana* and *Homoeosoma electellum*, which feed on sunflower in Missouri. Cushman (*1927*) stated that it attacks the larva probably when young and leaves it while still a larva, and it spins a dense dark-brown cocoon. MacCreary and Stearns (*1955*) observed that the adult is capable of sustained flight. They captured it at a lighthouse 3 miles off the shore of Delaware and New Jersey.

It is a common parasite of *Epiblema strenuana*, and its occurrence in that host has been studied by Haden (*1935*) in Delaware, Putnam (*1935b*, *1938*) in Ontario, and Schread et al. (*1942*) in Connecticut. The author has also reared it in New Jersey from both summer and overwintering generations of *E. strenuana*.

T. epagoges is an occasional parasite of the oriental fruit moth. In Delaware Stearns and Amos (*1941*) reared four from this host over a 10-year period, and Bobb (*1942*) recovered several from Botetourt and Albemarle Counties, Va.

In the rearing work at the Moorestown laboratory between 1930 and 1944, 30 were recovered from the oriental fruit moth, in two of which host remains were examined microscopically. The counties from which *epagoges* was recovered were New Haven, Conn., Sussex, Del., Elkhart and Knox, Ind., Van Buren, Mich., Burlington, Gloucester, and Mercer, N.J., Orleans, N.Y., Knox, Ottawa, and Wayne, Ohio, Bucks, Franklin, and Lancaster, Pa., Botetourt, Va., and Berkeley, W. Va. It was not reared from any of the many collections taken from North and South Carolina, Georgia, Tennessee, Illinois, or Missouri.

Temelucha carpocapsae (Cushman)

Temelucha carpocapsae is a rare species, which was reared from *Carpocapsa pomonella* in Ohio in 1927 (Cushman *1930*) and from the oriental fruit moth also in Ohio (Neiswander *1936*). In the work at the Moorestown laboratory it was reared from oriental fruit moths in infested peach twigs collected at Cheshire, Conn., Bridgeboro and Princeton, N.J., Danville and West Richfield, Ohio, and Stewartstown, Pa. In two specimens the host remains were determined by microscopic examination.

Temelucha cookii (Weed)

Temelucha cookii is a common parasite of *Ancylis comptana fragariae*. Although this host is frequently abundant in and near peach orchards, *cookii* has rarely been recovered from the oriental fruit moth. In the work at the Moorestown laboratory where all insects were isolated before emer-

gence, one *cookii* specimen was reared from infested peach twigs collected at Tysons Corner, Va., four from Ridge Springs, S.C., and one from Princeton, N.J. Unfortunately the host remains were not examined. However, since several specimens were reared, there is only a remote possibility that the host was not the oriental fruit moth.

Temelucha Spp.

Two specimens of undescribed *Temelucha* (Oriental Fruit Moth Investigations Nos. 949 and 2505) have been reared from the oriental fruit moth. One was from a cocoon removed from a trap band exposed on a peach tree at Avon Lake, Ohio, from July 21 to September 1, 1932, and one was from a lot of infested peach twigs collected on July 14, 1936, at Walker, N.Y. The host remains were examined and identified as this host.

Labrorychus prismaticus (Norton)

Labrorychus prismaticus and the closely related *Atrometus clavipes* (Davis) adults differ from other parasites of the oriental fruit moth in having an extremely narrow stigma in the forewing (fig. 13).

The distribution of *prismaticus* according to Townes (*1945*) includes the Canadian Provinces of Quebec and New Brunswick and Maine, Vermont, Massachusetts, Connecticut, and Ohio—areas mostly north of commercial peach growing. Townes listed two hosts, the tortricid *Archips cerasivoranus* and the pyraustid *Pyrausta penitalis* Grote. Wishart (*1943a*) found that in southwest Ontario from about 1940 to 1942 nearly 80 percent of the pupae of the multiple strain of *Pyrausta nubilalis* were parasitized by *prismaticus*. He thought the parasite's abundance might be associated with the presence of the common alternate host *A. cerasivoranus* in the same area.

Baird (*1918*) observed that in Nova Scotia 25 to 30 percent of the larvae of *A. cerasivoranus* were parasitized by *prismaticus*. The parasite eggs were deposited in the body cavity, usually near the fourth or fifth segment. The parasite larvae grew very slowly until after the host had pupated. Then they started to feed voraciously, always with the anal end directed posteriorly in the host pupa. When mature, they turned around in the empty pupal case and pupated in that position. About 10 days after pupation they emerged and soon mated, but although maintained for more than 5 weeks in breeding cages, there was no apparent development of eggs. This led the author to suspect that the parasites overwintered as adults.

Baker et al. (*1949*) also reported that *prismaticus* is an occasional parasite of *P. nubilalis*. They observed that it attacked the larva but emerged from the pupa and that larvae parasitized by this species usually pupated before the nonparasitized larvae.

At the Moorestown laboratory four specimens of *prismaticus* were reared from oriental fruit moths collected as larvae in peach twigs at Staunton and Monroe, Va. The host remains of each were microscopically examined. Three were identified by R. A. Cushman at the U.S. National Museum and three were observed issuing from the host pupa.

Atrometus clavipes (Davis)

(Fig. 13)

Townes (*1945*) indicates that *Atrometus clavipes* has been reported from Quebec, Ontario, Michigan, New York, and Ohio. He listed three hosts—*Psilocorsis* sp.

(an oecophorid), *Acleris variana* (Fernald) (a tortricid), and the oriental fruit moth (an olethreutid). Stultz (*1955*) observed parasitism of the olethreutid *Spilonota ocellana* (Denis & Schiffermüller) in Nova Scotia apple orchards, where parasitization was seldom over 1 percent, and also that DDT and arsenical sprays did not adversely affect the rate. There are two published reports of *clavipes* reared as a parasite of the oriental fruit moth—one in Ontario (Van Steenburgh *1935*) and the other in Ohio (Neiswander *1936*).

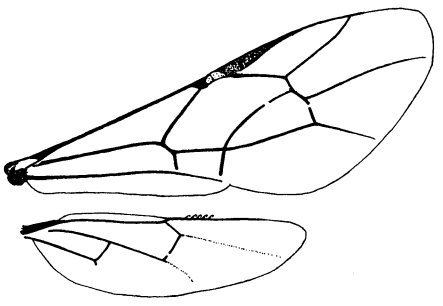

FIGURE 13.—Wings of *Atrometus clavipes*.

In the rearing done at the Moorestown laboratory 19 *clavipes* specimens were reared as larval parasites of the oriental fruit moth in peach twigs, nearly all of which were obtained from 1933 through 1935. They were recovered from Newburgh and Spring Valley, N.Y., Lawrenceville, N.J., Arendtsville and Biglerville, Pa., Ringgold, Md., and Broadway, Harrisonburg, Staunton, and Timberville, Va. In 17 parasite specimens the host remains were examined microscopically. All issued from the pupa of the oriental fruit moth.

Species in Other Families

Trichogramma minutum Riley

Trichogramma minutum, a cosmopolitan species of the chalcidoid family Trichogrammatidae, occurs in all sections of the United States and Canada infested by the oriental fruit moth. Martin (*1928*) referred to more than 150 host species, representing the orders Megaloptera, Lepidoptera, Coleoptera, Hymenoptera, Neuroptera, Diptera, and Hemiptera. Most of the hosts are Lepidoptera. Muesebeck et al. (*1951*) listed 110 hosts in America north of Mexico, of which more than half are Lepidoptera. Entomologists have studied, propagated, and liberated *minutum* in many parts of the world, and there is voluminous literature on their work. The following review is restricted to references on *minutum* as a parasite of the oriental fruit moth and includes a few related biological studies. Several references that are merely annual progress notes are omitted.

One of the most detailed studies of *minutum* was made by Peterson (*1930*) in New Jersey. He used the oriental fruit moth and *Carpocapsa pomonella* as hosts. He observed that in New Jersey two strains attacked the oriental fruit moth, one with dark-colored adults and the other, at least in midsummer, with lemon-yellow females. He was unable to hybridize the strains, and there were recognizable biological differences. His observations on biology were concerned principally with the yellow strain.

He found that at midsummer temperatures *minutum* females lived for several days, but if hosts

were abundant, they deposited most of their eggs on the first day. This parasite, of course, attacked and issued from the host egg. Insofar as is known it is the only species of true egg parasite of the oriental fruit moth. After oviposition, females sometimes appeared to feed at the egg-laying puncture. The parasite eggs soon hatched into elongate larvae, which were active for about 24 hours. After 28 hours they became much enlarged and inactive. Darkening of tissues about the parasite, so characteristic of this species, occurred after 48 hours and emergence after 200 hours or more. Mated females produced a small excess of females, and unmated females produced only males. Parasitism caused an immediate cessation of all development of the host, and host eggs were successfully attacked at any stage preceding the development of the larval head capsule.

During much of the summer the life cycle for *minutum* in New Jersey was 9 to 16 days, but in colder weather it was as much as 53 days. There was a possible maximum of 13 generations a season. Naturally overwintering stages were not discovered, but *minutum* did overwinter successfully outdoors in laboratory-parasitized eggs of the oriental fruit moth, *Anagasta kühniella* (Zeller), and *Thyridopteryx ephemeraeformis*. From one to four parasites developed in each oriental fruit moth egg, and one female parasitized on an average 40.2 eggs in 1927 and 35.9 in 1928.

Van Steenburgh (*1934*) in experiments in Ontario used three strains of *minutum* on the oriental fruit moth. He concluded that the parasite did not occur early enough and in sufficient numbers to be significant in controlling this pest. He worked with three strains that he considered biologically distinct and that he was unable to cross. They were a "gray race" from California, a "dark" strain found attacking the eggs of *Sialis infumata* Newman in Ontario, and the native yellow race that normally attacked the oriental fruit moth in Ontario.

In Ontario parasitism of oriental fruit moth eggs did not usually occur until early July, was more common in eggs laid on quince than on peach, and was usually highest at peak host-egg production, with average parasitization up to 23 percent. In one experiment he found that parasitism of this host's eggs was highest on the border of an orchard next to a woodland and decreased toward the center of the orchard. He did not obtain any overwintering *minutum* specimens from leaves of peach dropped in the fall, and he failed to overwinter the parasite outdoors in laboratory-parasitized oriental fruit moths obtained in the fall.

He found that in Ontario eight generations of *minutum* were possible before the peach crop was harvested. He observed that adults dispersed from a tree having only a few host eggs. Emergence was speeded up by increasing the light intensity even at constant temperatures. Adults ran rapidly over leaves but also frequently took flight, after appearing to jump several inches clear of the leaf surface. Adult activity increased with increased light intensity. In a very light breeze, flight was windward, but at 3 miles per hour or more the flying insects were carried with the wind. Rain did not appear to trap many insects, which during precipitation remained sheltered on the undersurface of leaves. In laboratory observations lime and oil sprays inhibited normal parasitism of oriental fruit moth eggs.

Jaynes and Bynum (*1941*) working with *Diatraea saccharalis* in Louisiana confirmed much of the

biology of *minutum* reported on other hosts. They attempted to determine how the parasite overwintered. One adult was captured in midwinter. However, they were doubtful that either individuals of the adult or any of the immature stages of the parasite survived from fall to spring. They thought that adults probably emerged on warm winter days and parasitized such host eggs as were available. They trapped several species of Lepidoptera between January 13 and February 16. From 53 individuals, eggs were obtained that were parasitized by *minutum* in the laboratory. They found that in the canefields *minutum* adults would disperse as far as 100 feet within 48 hours of release and that there was very high correlation between density of host eggs and rate of parasitism; the rate was highest when egg density was greatest.

T. minutum probably attacks other hosts than the oriental fruit moth near peach orchards earlier in the season. Garman (*1929*) observed parasitism of *Nematus ribesii* (Scopoli) on June 4, but the earliest parasitism of the oriental fruit moth in the same season was on July 26. Smith (*1929*) noted that several adults in the field were attracted to eggs for a distance of one-eighth inch, and one reversed its course and went to an egg one-half inch away. However, most eggs seemed to be encountered entirely by chance.

The parasitism of oriental fruit moths by *minutum* in orchards has been observed in Maryland (Garman *1917*, *1918*), the District of Columbia (Wood *1918*), New Jersey (Peterson *1926*, *1929*, Peterson and Haeussler *1926*), Connecticut (Garman *1927*, *1930b*), Pennsylvania (Stear *1929*), Georgia (Alden *1930*), South Carolina (Eddy et al. *1930*, Eddy and Nettles *1931*), and Ontario (Steenburgh *1930a*, *1931*, Van Steenburgh *1932*). Several of these authors observed that *minutum* was absent or scarce on this host early in the season but became more abundant in the middle of or late in the season and that the parasite was rarely abundant when host eggs were also not abundant.

There were several early attempts to propagate *minutum*, some of which appear to have been moderately successful. However, large-scale breeding was started in 1926, when Flanders used the breeding host *Sitotroga cerealella* (Olivier). The method he devised (*1927*, *1928*, *1929*) was so spectacularly successful that the parasite was soon propagated by the millions in scores of laboratories scattered over the world. Flanders' system adapted in various ways to meet local needs was used, and except for a few troublesome production problems such as mite infestations, the results were uniformly successful. As the basis for liberations, parasites in *Sitotroga* eggs were used. The eggs were freed of trash, glued to cards, exposed to parasites, incubated to the pupal stage, and stored until needed.

There were several experiments from 1929 to 1931 on the liberation of large numbers of laboratory-propagated *minutum* against the oriental fruit moth. Some workers found increased rates of parasitism after such releases, and a few implied that there was an associated reduction in fruit injury (Daniel *1930*, Garman *1930b*, Steenburgh *1930a*, Alden and Clarke *1931*, Flint and Chandler *1931*, Schread *1932*). However, enthusiasm for large liberations of *minutum* against this host soon died out, although releases were continued in Connecticut until 1938 (Garman *1939*) and in Georgia until 1944 (Alden *1944*). In New Jersey in 1930 and 1931 liberations were made in 16 blocks of peaches (Allen and

Warren *1932*), in which the results were checked against appropriate nonliberation blocks. There was slightly less fruit injury in the liberation blocks, but the difference was much too small to be of economic importance. Garman (*1933b*, *1939*) also reported unfavorable results from experiments on the mass liberation of *minutum*.

A strain of *minutum* that was recovered from the oriental fruit moth in Europe in 1931 (Allen et al. *1940*) was propagated on eggs of *T. ephemeraeformis* and in 1932 was released in 13 localities from Massachusetts to Florida. In 1933 a black strain discovered by Haeussler (*1940*) in Japan failed to increase on eggs of *T. ephemeraeformis* in New Jersey and was lost before suitable propagation could be started.

Genus PERILAMPUS

The species of the genus *Perilampus* are highly specialized chalcidoids of the family Perilampidae. Smith (*1912*) was the first to work out the life history of a perilampid. He found that the peculiar, active first-instar larva of *Perilampus hyalinus* Say, termed a planidium, after appearing on the body of a *Hyphantria* caterpillar entered it through the thin integument between segments and wandered throughout its body without feeding or doing any apparent damage to its tissues.

If a larva of the tachinid parasite *Variachaeta aldrichi* Townsend or the ichneumonid *Campoplex validus* (Cresson) were found in the caterpillar, *P. hyalinus* immediately entered one of these secondary hosts, where it developed as an endoparasite. However, at the beginning of hystolysis of the secondary host the *P. hyalinus* larva emerged and completed its development as an ectoparasite on the paralyzed body of the pupa of the secondary host. Because of a seasonal difference in the life cycle of these two primary parasites, *P. hyalinus* passed the winter as an endoparasite in the larva of *C. validus* and as an ectoparasite within the puparium of *V. aldrichi*. Smith found no evidence that *P. hyalinus* was ever a primary parasite of the lepidopterous host.

Several years later he (*1917*) found that *Perilampus chrysopae* Crawford deposited eggs near its host and that these hatched into the planidia that attached themselves to the larvae of passing hosts. He noted that the planidia might remain alive awaiting a host for as long as 17 days.

Clancy (*1946a*) published excellent illustrations of all stages of *P. chrysopae* and a review of the biological information on the genus *Perilampus*. There are many records of parasitism by species of *Perilampus* on Lepidoptera. However, Clancy observed that primary parasitism in this genus has been demonstrated only for *P. chrysopae* and one European species. He found furthermore that *P. chrysopae* will parasitize several species of *Chrysopa*, but that although they attach themselves readily to *Chrysopa majuscula* Banks, they fail to develop in it, although the planidia remain attached for several days. A review of his study of *P. chrysopae* follows.

The adults lived 20 to 58 days, with a preoviposition period of 3 to 11 days. They deposited eggs chiefly along the midrib on the undersurface of leaves. The normal capacity of the females was estimated at 200 to 500 eggs. The eggs were reticulated and milky white, with a stubby pedicel, and they were attached by a sticky exudate at the blunt end. They hatched in 4 to 6 days. There were three lar-

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val instars. The first instar, or planidium, was sclerotized except for a narrow ventral part, and had a ventral sucker on which it might erect itself or travel about by looping movements. It waved about frantically when a leaf was disturbed, and it attached itself at once to a host with its sharp mandibles if a passing host was touched.

Clancy observed that *P. chrysopae* always fed as an ectoparasite, but it started developing only when the host pupated. The host pupa gradually became paralyzed, although it remained alive for as long as 7 days after paralysis. At this stage parasitized pupae had a conspicuous glassy appearance. In the third instar the chrysopid pupa was rapidly reduced to a shapeless mass, although the parasite fed only on materials drawn through a small feeding puncture. The feeding period was 8 to 15 days. The parasite left a meconium of large, shining, cream-colored globules. Clancy was unable to induce this species to attack other primary parasites of chrysopids. Several planidia frequently attached themselves to one host larva, but only one adult ever emerged. Of 126 *P. chrysopae* adults examined, 83 were females.

Three representatives of the genus *Perilampus* were reared from the cocoons of the oriental fruit moth. Insofar as is known two were never primaries on this host, and the status of the third remains undetermined. Since the planidia of several species find their hosts within the bodies of caterpillars, which are not primary hosts, the status of the parasite cannot be determined except by breeding experiments or a very detailed examination of the host remains. Smulyan (*1936*) published a key to the species of *Perilampus*.

Perilampus fulvicornis fulvicornis Ashmead

Smulyan (*1936*) said that when *Perilampus fulvicornis fulvicornis* was reared from Lepidoptera, it occurred only as a secondary parasite. Muesebeck et al. (*1951*) stated that it occurs from Quebec to Florida and west to California and British Columbia. They listed as hosts four species of braconids, one ichneumonid, and one tachinid. They also listed 10 species of Lepidoptera, chiefly small caterpillars of fruitworms, stem borers, webworms, and leaf rollers, and including the oriental fruit moth. The author does not know of any of these Lepidoptera that have been proved primary hosts.

Boyce (*1941*) found that in Ontario from 1937 to 1939 *Perilampus*, including *fulvicornis*, parasitized 16 to 72 percent of the *Ascogaster quadridentata* issuing from *Carpocapsa pomonella*. He observed that planidia bored into both parasitized and unparasitized larvae of *C. pomonella* but never developed in the latter. Planidia overwintered in the fat bodies of *C. pomonella* larvae and entered *Ascogaster* larvae only when they resumed development in the spring. The planidium issued from *Ascogaster* after it had cocooned and pupated, and it completed its development as an external parasite within the *Ascogaster* cocoon.

Nickels et al. (*1950*) observed that *fulvicornis* occurred as a secondary parasite of *Acrobasis caryae* and *Laspeyresia caryana*. In addition to the hosts mentioned by Muesebeck et al., they listed five braconids, one ichneumonid, and one bethylid, including the common oriental fruit moth parasites *Calliephialtes grapholithae* (Cresson) and *Phanerotoma fasciata*.

P. fulvicornis was never reared at the Moorestown laboratory as a

primary parasite of Lepidoptera. Haeussler (*1930*) reared it as a secondary parasite of the oriental fruit moth in New Jersey. From 1930 to 1937 *fulvicornis* was reared occasionally at the Moorestown laboratory from twig-infesting oriental fruit moth larvae collected in the following counties: Niagara, N.Y., Washington, Md., Albemarle and Augusta, Va., Oconee, S.C., and Hamilton and Lawrence, Ohio. Every examination of host remains proved it a secondary parasite. The primary hosts were *Macrocentrus ancylivorus*, *M. delicatus*, *Temelucha minor*, and the introduced *Horogenes molestae* (Uchida).

From 1952 to 1956 parasites from the oriental fruit moth, *Grapholitha prunivora*, and *C. pomonella* larvae were reared from over a hundred samples of unsprayed apples taken from localities in seven Eastern States. During this period adults of *Perilampus*, including *fulvicornis*, were reared from Connecticut, New York, New Jersey, Maryland, and West Virginia—167 from *C. pomonella*, 10 from the oriental fruit moth, and 3 from *G. prunivora*. An examination of the host remains proved that none were primary parasites. Nearly all were parasites of *A. quadridentata*, but a few issued from *P. fasciata* and *Macrocentrus* sp.

Perilampus fulvicornis prothoracicus Smulyan

Smulyan (*1936*) identified specimens of *Perilampus fulvicornis prothoracicus* from New Hampshire, Maryland, and Louisiana to Nebraska and Washington, and stated that although this subspecies was recorded as a parasite of *Carpocapsa pomonella*, it was probably hyperparasitic on that host.

At the Moorestown laboratory it was reared in 1936 and 1939 from twig-infesting larvae of the oriental fruit moth collected in Martinsburg, W. Va., Clearbrook, Va., and Kimmswick, Mo. Once the primary host was *Macrocentrus delicatus*. It was probably a secondary parasite in the other hosts, whose remains were not examined.

Perilampus stygicus Provancher

Smulyan (*1936*) found *Perilampus stygicus* distributed from Canada through the Northeastern States to Virginia, and in Ohio, Kansas, and Louisiana. It is recorded as parasitic on *Macrocentrus*. Smulyan stated that in *Epiblema strenuana* this parasite occurs only as a hyperparasite.

At the Moorestown laboratory it was reared, presumably as a secondary parasite, from the twig-infesting larvae of the oriental fruit moth from Lovingston, Va., and Henderson, Ky., in 1938. The host remains were not examined.

SPECIES THAT ATTACK COCOONS

There are at least 41 species and subspecies of parasites that have been reared from oriental fruit moth cocoons, 20 of which are to be found in 12 genera of Ichneumonidae and 21 in 12 genera of Chalcidoidea. Most of these species occur only in North America and have adapted themselves to the oriental fruit moth since it became established in the United States. Generally these species attack several other hosts in which they may occur more abundantly than in this host. Some have been reared more frequently on this host than any other host, and several have been found in no other host.

In three genera—*Syntomosphyrum*, *Dibrachys*, and *Goniozus*—

several parasite adults issue from each host cocoon. In all other genera it is unusual for more than one adult to mature in each cocoon. Most of the cocoon parasites develop as ectoparasites on pupae or cocooned larvae of the oriental fruit moth, but several species, including those in *Pimpla*, *Itoplectis*, *Phaeogenes*, and the Chalcididae, are endoparasites of the pupae. No internal parasites of the cocoon larvae have been discovered.

Nearly all the species attack the host by piercing the cocoon and its shelter with the ovipositor, but *Phaeogenes* and possibly *Goniozus* enter the cocoon to oviposit. Many sting and permanently paralyze the host at the time the eggs are laid, but in some hosts paralysis does not develop until after the parasite eggs have hatched. For some parasite species, nearly all the host individuals are successfully parasitized. The females of other parasite species lay eggs on many individuals, which die prematurely, and some feed on the blood of individuals that are not parasitized. Where many hosts die prematurely or are destroyed by blood-feeding adults, the effect of the parasite on the host population is grossly underestimated when it is based only on the number of parasites that complete development and emerge.

Few species (possibly none) that are reared from oriental fruit moth cocoons are always secondary parasites. However, the primaries extend in a series from those that are always primaries to those that are almost always secondaries.

Several species, such as *Phaeogenes walshiae walshiae* (Ashmead), are known only as parasites of Lepidoptera with habits somewhat similar to those of the oriental fruit moth. Others, like *Dibrachys cavus* (Walker), have hosts in several orders of Insecta, and some, including *Gelis*, *Lymeon*, and *Arachnophaga*, are common parasites of the egg sacs of spiders.

The sex ratio varies widely between different species reared from oriental fruit moth cocoons taken from orchards. No males of *Gelis tenellus* (Say) have ever been reared. Males occur, but are relatively uncommon in several species, as in *Eurytoma appendigaster* (Swederus). The sexes are about evenly divided in some species, and in a few, such as *Pimpla inflata* Townes, males generally greatly outnumber females. In several species propagated in the laboratory, with honey as a food and the oriental fruit moth as a host, the progeny of females kept in breeding cages with males were largely or entirely males. Unmated females of several species produced only males, but in others, such as *Eupelmus limneriae* Howard, at least some of the unmated females produced female progeny.

In the breeding tests at the Moorestown laboratory several species of parasites completed the life cycle from oviposition to adult in the extremely short period of 10 to 12 days, a much shorter time than the minimum of 22 to 24 days required for the oriental fruit moth host. Adults of all the species studied had a short preovipositional period of not over 3 days and a long reproductive period (frequently well over a month), which broadly overlapped the reproductive period of their F_1 progeny and sometimes even the F_2 progeny. This condition differs from that of most larval parasites of the oriental fruit moth, in which the life cycle is the same length as that of the host and the adults have an average life span of only a few days.

It is not always possible to obtain the adult parasite that has emerged from an oriental fruit moth cocoon. Identification from remains in the cocoon is desirable. The presence

in one cocoon of several meconial clumps, pupal exuviae, or parasite cocoons showing the development of several parasites on one individual prove the occurrence of one of three easily identified species. All the chalcidoids and several of the ichneumonids have no silken cocoons. Several species issue only from the host pupae, and the manner of exit is characteristic, except that no differences have been noted between the four species of chalcids studied by the author. In some species the pupal remains of the parasite are rigid and black, whereas in others they are delicate and membranous.

In several species the manner in which the emerging parasite cuts its way out is fairly distinctive. Some species completely consume all the soft tissue. Others leave residues that dry up and stiffen, mummify, or darken the host remains. In several species ovipositing females leave round holes through the cocoon shelter, and in the blood-feeding species the holes may be bordered with the dark stains of dried blood. Sting scars in the host are sometimes fairly distinctive in number and position. Eggshell remains in *Eurytoma* and *Eupelmus* serve to identify these genera. Among those that form cocoons there are specific differences in the color and texture of the silk, the shape of the cocoon, and where it is formed in respect to the host remains. One species packs its cocoon with a conspicuous ball of gnawed fragments of silk and of host exuvium.

Ichneumonidae

KEY TO GENERA OF ICHNEUMONIDAE ATTACKING ORIENTAL FRUIT MOTH COCOONS

1. First segment of abdomen stalked, usually more than twice as long as basal width 5
   First segment of abdomen not stalked, usually not more than twice as long as basal width 2
2. Inner eye margins only slightly emarginate; abdominal tergites not bordered with white apically 3
   Inner eye margins conspicuously emarginate; abdominal tergites bordered with white apically ..... *Itoplectis*
3. Angle in nervellus of hindwing far cephalad of middle; exserted section of ovipositor less than half as long as abdomen ..... *Pimpla*
   Angle in nervellus of hindwing not cephalad of middle; exserted section of ovipositor more than half as long as abdomen 4
4. Slender species with abdomen more than twice as long as thorax; exserted part of ovipositor much longer than abdomen ..... *Calliephialtes, Apistephialtes*
   More robust species with abdomen scarcely twice as long as thorax; exserted part of ovipositor at most slightly longer than abdomen ..... *Scambus*
5. Females with wings 6
   Females wingless ..... *Gelis*
6. Not wholly red; ovipositor exserted for more than length of two apical abdominal segments 7
   Wholly red except eyes and two apical abdominal segments; ovipositor exserted for less than length of two apical abdominal segments ..... *Phaeogenes*
7. With areolet 8
   Without areolet; propodeum with spines ..... *Phobetes*
8. Areolet at least partially closed on side nearest wingtip 10
   Areolet open on side nearest wingtip 9
9. Thorax and abdomen without conspicuous white markings 11
   Thorax and abdomen with conspicuous white spots and bands ..... *Lymeon*
10. Two carinae on top of first abdominal tergite; notaulices distinct ..... *Mastrus*
    No carinae on top of first abdominal tergite; notaulices faint ..... *Gelis*
11. Section of areolet on radius shorter than adjoining abscissae ..... *Cryptus*
    Section of areolet on radius at least as long as adjoining abscissae ..... *Gambrus*

Genus SCAMBUS

The wing (fig. 14, *A*) differs from that of other ichneumonid parasites of the oriental fruit moth, except *Calliephialtes* and *Apistephialtes*, in having the areolet quadrate and nearly trapezoidal without an abscissa on the radius, the nervulus of the forewing joining the median vein opposite the basal vein, the hindwing with the hooks on the costal margin conspicuous, and with the nervellus angulate caudad of its middle. Two species have been reared from the oriental fruit moth.

KEY TO SPECIES OF SCAMBUS ATTACKING ORIENTAL FRUIT MOTH COCOONS

1. Tibia and tarsus of hindleg with alternating black and white rings
hispae (Harris)
Tibia and tarsus of hindleg fulvous to smoky without distinct rings
pterophori (Ashm.)

Scambus hispae (Harris)

(Fig. 14)

Since it was originally described in 1835 *Scambus hispae* has been known by several other names, and in much of the recent literature it has been called *Epiurus indagator* (Cresson). It is a polyphagous species, and it is chiefly a primary parasite of Lepidoptera. Walley (*1953*) reared several from *Choristoneura pinus* Freeman in Ontario. Coppel (*1947*) stated that it is both a primary and secondary parasite of *Choristoneura fumiferana* in British Columbia, and Dondale (*1954*) in Nova Scotia reared it occasionally from *Agathis laticinctus* (Cresson), a primary parasite of *Spilonota ocellana*. Townes (*1944*) listed as hosts 35 species of Lepidoptera, 1 tenthredinid, and 1 cynipid, and he gave distribution records from Nova Scotia and Ontario south to Alabama and Texas and in British Columbia and Washington. The lepidopterous hosts are widely diverse in habitat, habit, and size, ranging from leaf miners and stem borers to large foliage-feeding caterpillars such as the lymantriids.

Very little biological information is available. This parasite has been reported as attacking matured larvae and cocooned prepupae or pupae. Porter and Garman (*1923*) stated that it oviposited within the full-grown larva of *Anthophila pariana*. Haeussler (*1930*) reported that it occurs as an external parasite of the oriental fruit moth, and Dondale found the larvae ectoparasitic on *Agathis*. Cushman (*1927*) observed that in *Rhyacionia frustrana* the cocoon is a thin silken lining within the burrow of the host. Several other workers observed that similar cocoons are formed when the parasite issues from other hosts. Balduf (*1937*) found that in *Thyridopteryx ephemeraeformis* two adults sometimes issue from one host and that it overwinters as a mature larva within the chrysalis. Beacher (*1947*) observed that adults reared from *Coleophora malivorella* lived for 4 to 12 days when provided with food and that the sexes were about equal in number.

Two *hispae* parasites were reared in 1934 from the cocoons of *Macrocentrus ancylivorus*, a primary parasite of *Ancylis comptana fragariae* collected from raspberry at Parry, N.J.

S. hispae has been reported as an oriental fruit moth parasite by Stearns (*1928*), McConnell (*1928*, *1932*), Haeussler (*1930*), Daniel et al. (*1933*), Merritt (*1933b*), Van Steenburgh (*1935*), and Brunson and Allen (*1948*). In this host the recorded distribution includes Ontario, New York, Michigan, New

Jersey, and Maryland. Some of these authors stated that it is a primary parasite of oriental fruit moth cocoons.

In the rearing work done at the Moorestown laboratory *hispae* was not reared frequently from the oriental fruit moth despite the fact that it is a common parasite of numerous Lepidoptera occurring in the same environment. From the thousands of insectary-reared cocoons exposed each year in New Jersey peach orchards from 1931 to 1936, it was reared only in 1931 and 1933. The host remains of 13 *hispae* emergents were examined and all proved to be primary parasites. One

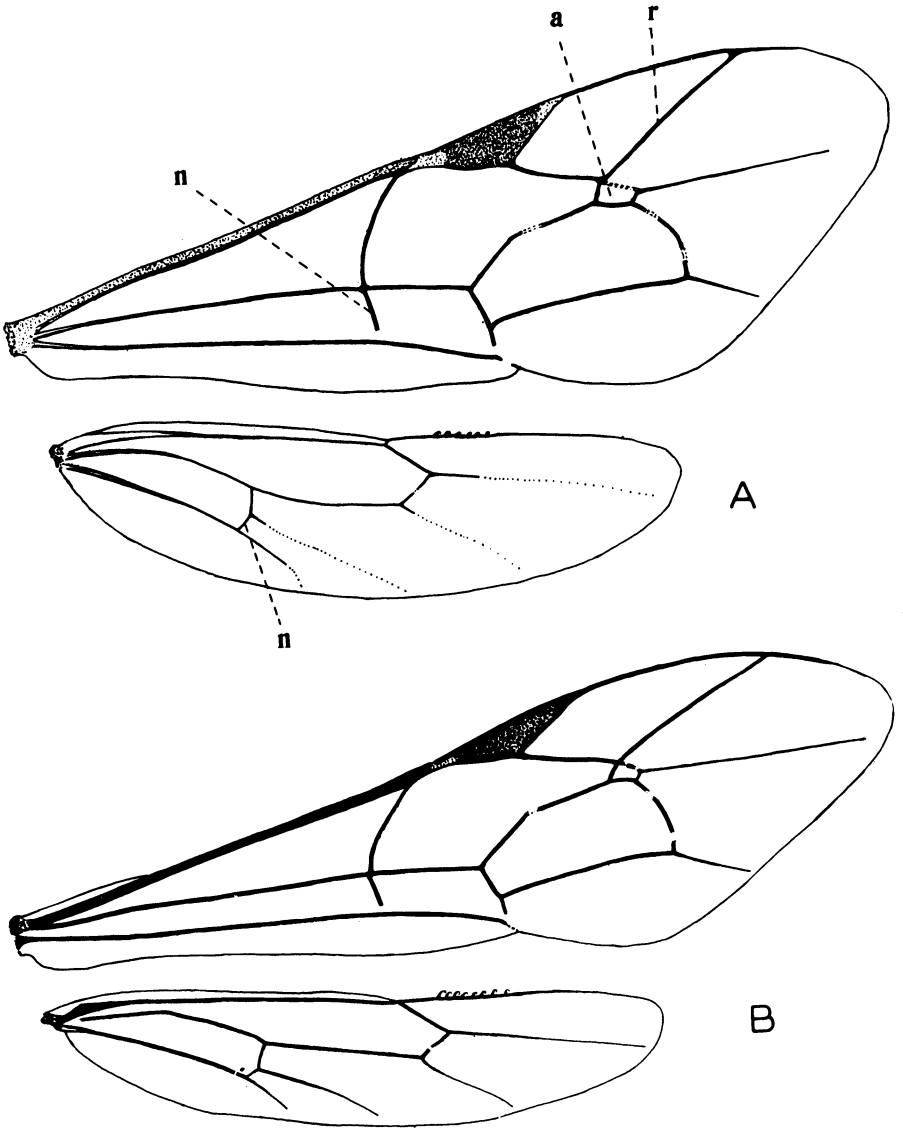

FIGURE 14.—*A*, Wings of *Scambus hispae*, showing areolet (*a*), nervulus of forewing and nervellus of hindwing (*n*), and radius (*r*). *B*, Wings of *Calliephialtes grapholithae*.

issued from the host pupa, the others from the prepupae. It was never reared as a secondary parasite of the oriental fruit moth. In some specimens no cocoon was evident, in others there was a very thin cocoon coextensive with the wall of the host cocoon. Twenty-two out of twenty-six adults reared from the oriental fruit moth were females.

Scambus pterophori (Ashmead)

Townes (*in* Muesebeck et al. (*1951*)) stated that the distribution of *Scambus pterophori* is transcontinental in the Canadian, Transitional, and Upper Austral Zones. Townes (*1944*) recorded 1 curculionid, 1 tenthredinid, and 16 lepidopterous hosts, most of which are stem or seed-pod borers or gall makers in plant stems. Cushman (*1926*) stated that this species belongs in the group of external-feeding ichneumonids, in which the female stings and permanently paralyzes or immediately kills the hosts, which she reaches by piercing the enclosing plant tissues, the host cocoon, or the pupal wall. He stated that *pterophori* attacks lepidopterous or coleopterous larvae living in weed stems and also sawfly larvae such as *Ametastegia glabrata* (Fallén) when they enter weed stems to pupate.

Hamilton (*1894*) found that the *pterophori* larva clings by its mouth to the curculionid larva of *Mononychus vulpeculus* (Fabricius) in the seed pods of iris. When the host larvae are young, two or three may be attacked in succession, but when they are full grown, one is sufficient. He stated that the parasite pupates within the host cell without forming a cocoon. Vinal and Caffrey (*1919*) found the larvae feeding through the ruptured walls of *Pyrausta nubilalis* pupae. Leiby (*1922*) observed that it destroys the larvae of *Gnorimoschema gallaesolidaginis* and pupates naked in the gall chamber. Wilder (*1927*) found that when *Mompha eloisella* Clemens in evening-primrose (*Oenothera*) is parasitized, the parasite overwinters as a yellowish-white larva in a thin network of silk spun in the feeding cavity beside the remains of the host larva. Balduf (*1929*) found that *pterophori* kills the larvae of *Achatodes zeae* (Harris) in its cell and spins a thin silk cocoon. He described the full-grown larva as yellowish white, with a densely tuberculate cuticle and with four sclerotized longitudinal bands on the top of the head.

Several workers observed that the adults issue through round holes gnawed through the walls of the plant stem, gall, or seed capsule. Schread et al. (*1942*) reared it as a parasite of overwintering *Epiblema strenuana* in 23 towns in Connecticut from 1939 to 1941.

At the Moorestown laboratory one specimen of *pterophori* was reared in 1932 from a common lepidopterous borer in the stems of *Bidens*. It emerged on April 15, after overwintering in host material collected on October 16. Although *pterophori* occurs commonly in weed-infesting insects and must be present in considerable numbers near peach orchards, it was rarely reared from the oriental fruit moth. One specimen was reared at the Moorestown laboratory in 1945 from a small lot of peach twigs infested with oriental fruit moths from Liberty Corner, N.J. Garman (*1938*) reared one specimen from trap bands removed from peach orchards, in which the host was presumed to be the oriental fruit moth.

Genera CALLIEPHIALTES and APISTEPHIALTES

Calliephialtes and *Apistephialtes* adults reared from the oriental fruit

moth are usually large. The female has an ovipositor that is much longer than the abdomen. The male is slender, with an abdomen more than twice the length of the thorax. The wing venation (fig. 14, *B*) closely resembles that of *Scambus*, but it differs in several respects from that of other cocoon parasites of the oriental fruit moth. The two species that have been reared from oriental fruit moth cocoons are *C. grapholithae* (Cresson) and *A. variatipes* (Provancher).

KEY TO SPECIES OF CALLIEPHIALTES AND APISTEPHIALTES ATTACKING ORIENTAL FRUIT MOTH COCOONS

1. Thorax fulvous; legs white with longitudinal black stripes_*C. grapholithae* (Cress.)
   Thorax black with fulvous spots; legs usually fulvous without longitudinal black stripes except on outside of hindtibia_____*A. variatipes* (Prov.)

Calliephialtes grapholithae (Cresson)

(Fig. 14)

The distribution of *Calliephialtes grapholithae* as reported by Muesebeck et al. (*1951*) lies within the Lower and Upper Austral Zones and warmer parts of the Transitional Zone from the Atlantic Ocean to 100° W. *C. grapholithae* has been recorded as attacking one tenthredinid and a few species of Lepidoptera whose larvae are casebearers or borers in stems, fruits, or nuts. It has been most frequently reported as a parasite of *Laspeyresia caryana*, *Acrobasis juglandis* (LeBaron), and the oriental fruit moth, and it has also been reared from *Carpocapsa pomonella* and *Epiblema strenuana*.

There is a little published information on the biology of *grapholithae*. Several workers noted that it attacked cocooned oriental fruit moths. Haeussler (*1930*) reared it from oriental fruit moths on quince and observed that the parasite was external to the host. Hamilton (*1890*) observed that the parasite issued from the prepupa of *L. caryana* and pupated within the pupal cell of the host in nut shucks without spinning a cocoon. Bottimer (*1926*) reported that the larvae developed singly in *Meskea dyspteraria* Grote and emerged from the gall of the host.

Nickels et al. (*1950*) published the most extensive biological observations yet made for this species. They reared it as a primary parasite of *Acrobasis caryae* and also occasionally as a secondary parasite of *Agathis acrobasidis* (Cushman). They found that the adults had a preovipositional period of 14 to 17 days. They stung and paralyzed fourth- and fifth-instar larvae and deposited unattached eggs, usually one to a larva, on or near it. Four females laid 144 eggs, with an average of 2 per day. The larvae fed externally on the host and spun a cocoon after leaving it. In September the development period from egg to adult was 16 days, of which about 1½ days were spent in the egg stage and 3 days as a feeding larva.

It has been reported as a parasite of the oriental fruit moth in New Jersey (Stearns *1927*, *1928*, Haeussler *1930*, Brunson and Allen *1948*), Ontario (Steenburgh *1931*), Michigan (Merritt *1933b*), New York (Daniel et al. *1933*), and Ohio (Neiswander *1936*).

At the Moorestown laboratory *grapholithae* was obtained occasionally from oriental fruit moth cocoons reared in the insectary and exposed in peach orchards in Burlington County, N.J., but in only three of the nine seasons in which such cocoons were exposed. It was a fairly common parasite in one or-

chard in 1931, occurring repeatedly in cocoon lots exposed during late May, June, and early July. When host remains were examined, *grapholithae* was proved the primary parasite of the oriental fruit moth. It destroyed the pupa in 23 specimens examined.

Apistephialtes variatipes (Provancher)

Apistephialtes variatipes has been found in Ontario, New York, New Jersey, Maryland, and West Virginia (Townes *in* Muesebeck et al. (*1951*)). From 1928 to 1934 several workers in the Eastern Coastal States reared it from oriental fruit moth cocoons. Jaynes and Marucci (*1947*) reared it in considerable numbers from trap bands removed from lightly sprayed apple trees under circumstances that indicate that the host must have been *Carpocapsa pomonella*. There are no other recorded hosts.

At the Moorestown laboratory *variatipes* was reared rarely from the oriental fruit moth and only from overwintering cocoons. In Burlington County, N.J., three specimens were reared in the early spring of 1926 and 1927 from cocoons collected from quince during the winter, and one specimen was reared in 1933 from oriental fruit moth cocoons collected on peach the preceding fall. Adults were also reared from cocoons collected on peach at Farmington, Conn., in the fall of 1932. Its relationship to the oriental fruit moth was proved by examination of host remains. It is unquestionably a primary parasite and apparently attacks the prepupae.

Genus PIMPLA

The *Pimpla* species parasitic in the oriental fruit moth are black ichneumonids, in which the exserted part of the ovipositor is scarcely half the length of the abdomen. The nervellus of the hindwing (fig. 15, *A*) is angulate cephalad of the middle as in *Itoplectis*, but *Pimpla* differs from it in having the abdominal tergites black to the apices and the inner eye margins only slightly emarginate (fig. 16, *C*).

Townes (*1940*) recognized two closely related species, both of which are recorded as parasites of the oriental fruit moth, but he was unable to separate the males. The female is said to have the tibia strongly swollen in *Pimpla inflata* Townes and only moderately swollen in *P. aequalis* Provancher. L. M. Walkley at the U.S. National Museum examined all the *Pimpla* specimens at the Moorestown laboratory that were reared from the oriental fruit moth and taken at numerous widely separated localities, and she was able to distinguish only one species.

Pimpla aequalis Provancher

Townes (*1944*) listed *Pimpla aequalis* as a parasite of 28 species of Lepidoptera, including such diverse forms as wood borers, bagworms, casebearers, stem and wood borers, fruitworms, shuckworms, leaf rollers, and free-living foliage feeders. In all records examined by that author in which the mode of parasitism was defined, *aequalis* was a primary parasite that issued from host pupae. There seems to be some uncertainty regarding the extensively polyphagous nature of this parasite, since Townes (*in* Muesebeck et al. (*1951*)) listed as hosts only eight species of Lepidoptera. In both publications Townes included the oriental fruit moth as a host. In 1951 he stated that *aequalis* was distributed from the Atlantic Ocean to 100° W. in the Transitional and Upper and Lower Austral Zones. Townes (*1939*) observed that the adults when disturbed gave off a strong odor.

Townes (*1944*) in his bibliography recorded that *aequalis* was reared from the oriental fruit moth in Ontario (Smith *1929*, Van Steenburgh *1935*), Virginia (Stearns *1919*), New Jersey (Haeussler *1930*), Michigan (Merritt *1933b*), South Carolina (Nettles *1934*), Maryland (McConnell *1934*), Delaware (Haden *1935*, Stearns and Amos *1941*), Ohio (Neiswander *1936*), and Connecticut (Garman *1938*).

Pimpla inflata Townes

(Figs. 15 and 16)

Pimpla inflata was described by Townes (*1940*) from a series including specimens from Quebec to Illinois and south to Florida and Texas and from specimens reared from *Carpocapsa pomonella*, *Gretchena bolliana*, and the oriental fruit moth. The last was reared at the Moorestown laboratory. In *inflata* the front tibia is conspicuously inflated (fig. 15, *B*). Townes (*in* Muesebeck et al. (*1951*)) recorded a distribution coextensive with that of *Pimpla aequalis* and recorded two additional hosts, *Synanthedon pictipes* (Grote & Robinson) and *Salebria tenebrosella* Hulst. The hosts he listed are all Lepidoptera. Brunson and Allen (*1948*) reported that *inflata* was one of the principal parasites of insectary-reared cocoons of the oriental fruit moth exposed in peach trees.

At the Moorestown laboratory *inflata* was reared from oriental fruit moth cocoons collected from peach trees in the following counties: Hampden, Mass., Burlington and Mercer, N.J., and Lancaster, Franklin, and York, Pa. In the cocoons collected in the field, parasitization by *inflata* was not high, probably because this parasite competed unsuccessfully with the dominant larval parasites. In parasite-free cocoons exposed in peach orchards in Burlington County, N.J., from 1932 to 1936 *inflata* was reared from 80 lots, in which its rate of parasitization among 2,461 cocoons was 8.0 percent. The highest rates of parasitization during these 5 years were, respectively, 47, 26, 31, 40, and 31 percent. They occurred from late June to early August.

At the Moorestown laboratory the remains of several hundred *inflata* insects, reared as parasites of

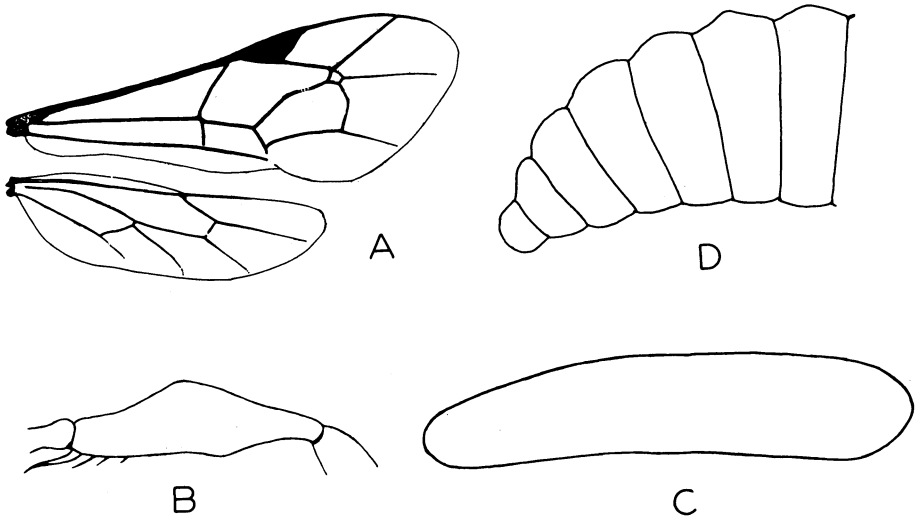

FIGURE 15.—*Pimpla inflata: A*, Wings; *B*, front tibia of female; *C*, egg; *D*, tip of abdomen of mature larva.

the oriental fruit moth, were examined. *P. inflata* always occurred as a primary parasite attacking young pupae. When excited, the adults emitted a strong pungent odor, resembling burned rubber, quite unlike any other parasite attacking the oriental fruit moth. Adults attacked insectary-reared cocoons when they were exposed in unsprayed peach or apple orchards and also when exposed in wooded areas far removed from orchards. Very few of the pupae that were attacked in the field failed to produce adult parasites, but in lots bred in the laboratory a considerable number of the pupae that were stung and permanently paralyzed received no parasite eggs. The ratio of females to males reared from oriental fruit moth cocoons exposed in orchards varied greatly. In 1956, 22 percent of 195 parasites reared were females. In 1957, 39 percent of 201 reared in June were females, but there were no females among the 34 reared in late July.

Adult parasites were confined with young host pupae in glass tubes, 4 by 1 inch, and provided with honey and drinking water. They appeared to mate readily and commenced oviposition 1 to 2 days after emergence. The longevity of the males used in the breeding tests averaged 13 days and the females 18 days. One female lived for 34 days. Females with progeny had an average reproductive period of 19 days from emergence and a maximum of 31 days. Unmated females had only male progeny. Very few females were obtained in the propagation experiments. The number of progeny per female ranged from 5 to 25, and 4 was the maximum produced per day.

The egg (fig. 15, *C*) was slender and translucent with a flexible, unsculptured surface. It was 0.8 by 0.2 mm. Only one mature egg usually occurred in the uterus of the female. In insectary-reared cocoons the ovipositing female pierced the cardboard covering the cocoon and the shell of the pupa to deposit her eggs in the semifluid body contents. The small, black, sclerotized spots where the pupa had been pierced usually were located on the dorsum of the first three abdominal segments or the posterior part of the thorax. Pupae that had been stung became permanently paralyzed a few hours after oviposition and before the eggs hatched. The abdomen was completely immobilized and the wing pads failed to develop, but the body contents remained fresh until they were completely consumed.

Paralyzed pupae were found to contain one or two eggs, but only one larva matured per pupa. The egg hatched about 1 day after oviposition into a free larva, which grew rapidly and soon became securely footed in the narrow posterior end of the host pupa, where it stayed during the remainder of the feeding period. It consumed first the tissue in the posterior part of the host, but as it approached maturity it cleaned out all tissue, consuming that in the anterior end last. The larva was full grown 5 days after oviposition. The full-grown larva had a subconical abdomen (fig. 15, *D*) and a translucent cuticle, through which the yellow-brown internal organs could be seen in the anterior dorsal region. There was a row of lateral callosities, and in the abdominal region there were some subcuticular white flecks. Six to eight days after oviposition the larva pupated, and subsequently the white pupa gradually changed to black. Adults emerged 11 to 22 days after oviposition. However, 65 percent of the emergence occurred in 12 to 14 days. Most of the females were still reproducing after their progeny had started to reproduce.

This parasite can usually be identified from remains in the host cocoon. The parasite issues from the host pupa, which has been carefully cleaned of all soft tissue. The parasite forms no cocoon and leaves no pupal remains in the host cocoon. The meconial remains in the posterior end of the host pupa are black and sharply defined. The emerging parasite tears away the entire cephalic end of the pupa and issues through the silken end of the cocoon. There are minor differences in the remains in the host pupa by which *inflata* may be distinguished from the nearly related *Itoplectis conquisitor* (Say).

Itoplectis conquisitor (Say)

(Fig. 16)

Adults of *Itoplectis conquisitor* may be distinguished from the closely related *Pimpla inflata* adults by the conspicuous white apices of the abdominal tergites and the deeply emarginate inner eye orbits (fig. 16, *B*). The wing venation is shown in figure 16, *A*.

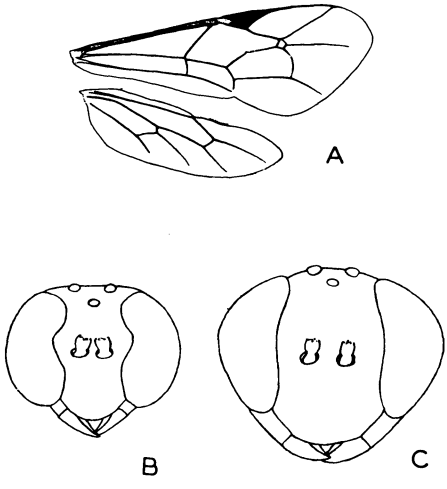

FIGURE 16.—*A*, Wings of *Itoplectis conquisitor; B*, outline of head of *I. conquisitor*, showing deeply emarginate eyes; *C*, outline of head of *Pimpla inflata*, showing slightly emarginate eyes.

More than a hundred years ago Gorham (*1847*) found that *Itoplectis* was an important parasite of *Alabama argillacea* (Hübner). Since then a number of other authors have observed its habits in several hosts. Brackett (*1865*) found that it destroyed 15 to 20 percent of the fall brood of *A. argillacea* and that it overwintered in dead *A. argillacea* pupae, but that it was rare on this host at other seasons. Howard (*1897*) published illustrations of the adult and immature stages. He noted that *Itoplectis* pupated within the pupae of *A. argillacea* without forming a cocoon. Weed (*1900*) observed that the adult deposited its eggs in the pupae or prepupae of *Malacosoma disstria* Hübner after piercing the silk wall of the cocoon with its ovipositor. Weed and Fiske (*1900*) found that it was the most important pupal parasite of *Malacosoma americanum* (Fabricius) in New Hampshire, but that it was also occasionally a secondary parasite through *Hyposoter fugitivus* (Say). Johnston (*1913*) found that adults habitually stung and fed on exuding juices of the prepupa and pupa of *Trichoplusia ni* (Hübner) and that other individuals were usually selected for oviposition. One adult oviposited in two cocooned larvae and five pupae in 1 day.

Balduf (*1937*) reared *conquisitor* females predominantly from female pupae and males predominantly from males of *Thyridopteryx ephemeraeformis*. He stated that this parasite overwintered in this host. There was an unusual variation (6.5 to 20 mm.) in the size of the females that issued from *T. ephemeraeformis*. There are scores of host records in the literature, in many of which *conquisitor* is reported to have been reared as a primary parasite issuing from the pupa. Townes (*1944*) listed as hosts 86 Lepidoptera of many families, 3 braconids,

and 5 ichneumonids. Baker et al. (*1949*) found that it attacked the larva of *Pyrausta nubilalis* but issued from the pupa. Dowden et al. (*1950*) observed that it attacked the prepupa or pupa of *Choristoneura fumiferana* and emerged from the pupa. Muesebeck et al. (*1951*) stated that it is distributed from the Atlantic Ocean to the Rocky Mountains in the Transitional and Upper and Lower Austral Zones.

I. conquisitor is one of the most common and extensively polyphagous parasites of Lepidoptera, with a transcontinental range in North America. It is a primary parasite of scores of common insect pests. It is a solitary internal parasite that attacks either prepupae or pupae and issues from the pupae, in which it pupates without constructing a cocoon. The adult oviposits within the host through a cocoon wall or a sclerotized pupal case and may feed on the blood of punctured victims.

I. conquisitor has been recorded as a parasite of the oriental fruit moth by Stearns (*1919*, *1928*), Haeussler (*1930*), Haden (*1935*), and Brunson and Allen (*1948*). Haeussler observed that it was an internal parasite attacking the cocoon. The recorded distribution as a parasite of the oriental fruit moth includes Connecticut, New Jersey, Pennsylvania, Delaware, and Virginia.

I. conquisitor was reared at the Moorestown laboratory as a parasite of oriental fruit moth cocoons that were collected in peach orchards only from Burlington County, N.J. In 1931 it was reared in large numbers from insectary-reared cocoons exposed in one peach orchard in Moorestown, in which the parasitization by this species between June 30 and August 1 ranged from 17 to 43 percent. It was reared from 13 lots of cocoons from 1931 to 1933 and in 1936, and the average parasitization in these lots was 14 percent. It was never reared as a hyperparasite of the oriental fruit moth. It was reared several times from overwintering cocoons of this host. Of the 88 specimens reared from this host in the Moorestown collection, only 16 percent were females.

At the Moorestown laboratory no life-history studies were made on this parasite, but the remains of several specimens that issued from the oriental fruit moth were studied. In all of these specimens the parasite issued from the pupa. Small sclerotized sting marks were found on several specimens, usually on the wing pads. Small round ovipositor holes through the cardboard covering of the cocoon indicated that oviposition occurred through the cocoon shelter. No silken cocoon was formed. The life history of *conquisitor* in the oriental fruit moth apparently is closely similar to that of *P. inflata*. However, the pupae that were parasitized by *conquisitor* had the meconial material more loosely packed, and the emerging parasite left attached to the host pupal case a slender part of the extreme anterior end.

Bathythrix peregrina (Cresson)

Although *Bathythrix peregrina* was described nearly 90 years ago, little information about it has been published. Townes (*1944*) gave its synonymy and stated that it had been found in Quebec, New Jersey, Connecticut, and Kansas.

In 1932 one specimen was reared from a lot of hibernating oriental fruit moth cocoons trapped on peach trees in late summer at East Longmeadow, Mass., and in which it was a parasite of *Glypta rufiscutellaris*.

Genus MASTRUS

Four species of *Mastrus* have been reared as primary or secondary parasites of the oriental fruit moth. They have the first abdominal segment stalked, with two carinae on its tergite. The notaulices are distinct and the areolet (fig. 17, *A*) is open on the side nearest the wingtip.

KEY TO SPECIES OF MASTRUS ATTACKING ORIENTAL FRUIT MOTH COCOONS

(Adapted from Cushman (*1917*))

1. Mesoscutum with distinct punctures 2
   Mesoscutum minutely granulate, without punctures or at most obscurely punctate in male ..... *pilifrons* (Prov.)
2. Mesoscutum granulate, finely punctured; abdomen black; ovipositor nearly as long as abdomen ..... *smithii* (Pack.)
   Mesoscutum highly polished; abdomen usually more or less red (may be black in male); ovipositor not nearly as long as abdomen ..... *carpocapsae* (Cush.)

Mastrus pilifrons (Provancher)

(Fig. 17)

Townes (*in* Muesebeck et al. (*1951*)) stated that *Mastrus pilifrons* is distributed transcontinentally in the Transitional and Upper Austral Zones. Although this species has been known since 1879, it has been found associated with only three lepidopterous hosts. Ashmead (*1896*) reported it as a parasite of *Acronicta betulae* Riley, and Townes (*1944*) listed several records of parasitism in *Carpocapsa pomonella*. However, it has been reported most frequently as a parasite of the oriental fruit moth (Stearns *1928*, Smith *1929*, Haeussler *1930*, McConnell *1932*, *1934*, Driggers *1932*, Merritt *1933b*, Van Steenburgh *1935*, Neiswander *1936*, Brunson and Allen *1948*). It has been reported as a parasite of this host in Ontario, Massachusetts, Connecticut, New York, New Jersey, Pennsylvania, Maryland,

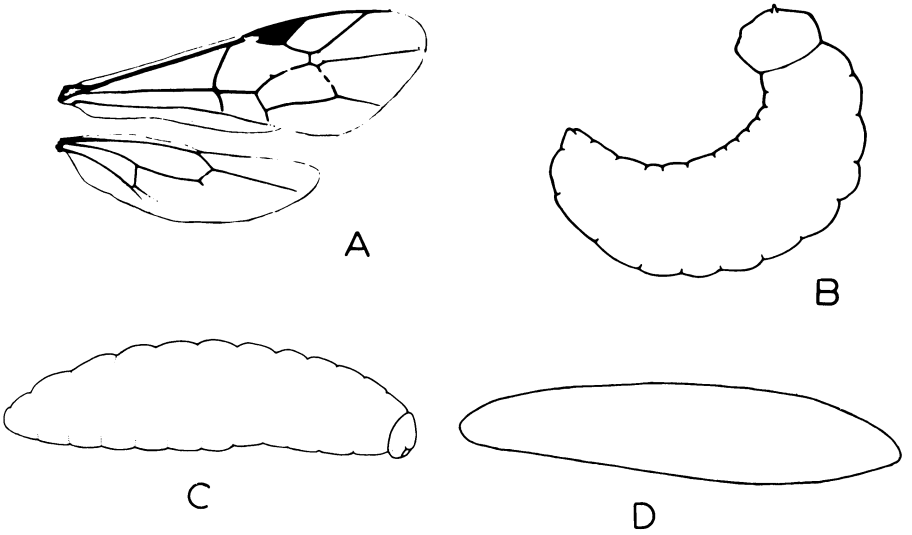

FIGURE 17.—*Mastrus pilifrons: A*, Wings; *B*, first-instar larva; *C*, mature larva; *D*, egg.

Virginia, Ohio, and Michigan. LePage and Fadigas (*1944*) stated that it was the most common pupal parasite of this host in Uruguay.

Very little of its biology is known. Haeussler (*1930*) thought that it was probably an internal pupal parasite. Driggers (*1932*) reared it from the hibernating generation of the oriental fruit moth. Brunson and Allen (*1948*) stated that it was a common primary parasite of oriental fruit moth cocoons and also occasionally a secondary parasite. Brunson (*1948*) found that it sometimes parasitized the common oriental fruit moth parasite *Macrocentrus ancylivorus*.

In 1931 and 1932 workers at the Moorestown laboratory reared *pilifrons* from oriental fruit moth cocoons collected in peach orchards in 17 counties as follows: Massachusetts 1, Connecticut 2, New York 3, New Jersey 2, Pennsylvania 4, Maryland 1, Virginia 2, and Ohio 2. It was also reared frequently as a parasite of insectary-reared cocoons exposed in orchards in Burlington County, N.J., from 1931 to 1936, and it occurred in successive lots exposed from mid-April to mid-October. It was frequently reared from oriental fruit moth cocoons collected late in the season and overwintered in the laboratory. Occasionally parasitization was in excess of 20 percent, and the highest was 50 percent. During this period *pilifrons* was reared from 80 collections, in which the parasitization was 5.0 percent of the 3,797 total parasites and hosts that emerged. This species was rarely a secondary parasite of the oriental fruit moth and not once among the 61 *pilifrons* specimens reared in 1931 and 1932 from field-collected cocoons. The host remains of 135 specimens were examined. In 128 specimens the prepupa was destroyed, and in 7, *pilifrons* issued from the pupa. In the collection at Moorestown 62 percent of the 93 mounted specimens are females.

Considerable new information on the biology of *pilifrons* was obtained in 1957. Only a few specimens were reared from the insectary-reared cocoons that were exposed, but these were from various environments, such as neglected peach orchards, abandoned apple orchards, and brushy woodlands.

When adults reared from field-exposed cocoons were confined in glass tubes with freshly formed oriental fruit moth cocoons, a moderate rate of propagation was obtained. Several female progeny were obtained in the F_1 generation, but although both sexes were associated in the breeding cage, the F_2 generation was entirely male. The first oviposition occurred about 2 days after emergence. The female ovipositied through the cardboard wall of the host cocoon, leaving very small ovipositor holes through the paper. The oriental fruit moth prepupae on which eggs were laid were always paralyzed. Sometimes several black sclerotized sting marks were visible, at other times none were discovered.

One to several eggs were deposited on the integument of the paralyzed host. The egg (fig. 17, *D*) was shining translucent white without sculpturing and was subconical at one end. It had a delicate, tacky membranous chorion so that it stuck readily to the body of the host. Active larvae hatched from the eggs 1 or 2 days after oviposition. Usually the number was soon reduced to one larva to a host.

M. pilifrons developed as an ectoparasite, which moved freely over the body of the host. The newly hatched larva (fig. 17, *B*) was translucent, with the tracheae and midgut plainly visible. The head was white and had well-developed antennae. As the parasite feeding

progressed the host body became shrunken, but decomposition of soft tissues was not evident. The more precocious larvae completed their feeding 5 days after oviposition. The mature larva (fig. 17, *C*) was about 5.6 by 1.8 mm. The head was white with small antennae. The thorax was opaque white with microscopic shagreening. The abdomen was white and had widely spaced subcuticular white flecks.

Cocoons were formed as early as 6 days after oviposition. Some were thin and white, others a semiopaque, dingy black. The texture was parchmentlike without woolly threads. The cocoon sometimes was found beside the shrunken elongated remains of a partially consumed prepupa, but it was more frequently found in one end of the cocoon cavity, with the partially consumed prepupal remains at the other end. The cocoon was usually angular and closely fitted to the end of the host cocoon. The individuals that formed thin, white cocoons pupated in 9 to 10 days and emerged in 13 to 18 days after oviposition; the largest numbers emerged on the 14th and 15th days. The parasites with blackish heavy-walled cocoons that were formed during late July and August and at the time many thin-walled cocoons were also being formed had a much longer life cycle. However, all of them emerged between September 25 and October 22.

The adult parasites tore away the end of their cocoons and usually emerged through the silken wall at the posterior end of the host cocoon. In some specimens the parasite pupa was apparently oriented toward the host remains, blocking the anterior end of the oriental fruit moth cocoon. In such cocoons the emerging parasite cut a hole through the middle of the cardboard shelter of the cocoon. A thin, wadded pupal pellicle was packed in the posterior end of the parasite cocoon with the meconium.

Mastrus smithii (Packard)

Mastrus smithii has been recorded from Quebec, Maine, Connecticut, Illinois, and Washington, and it is parasitic on *Trichotaphe levisella* Fyles (Gelechiidae), *Ametastegia glabrata* and *Macremphytus tarsatus* (Say) (Tenthredinidae), and *Gambrus extrematis* (Cresson) (Ichneumonidae) (Townes *1944*). Marsh (*1937*) studied its biology as a hyperparasite of *Samia cecropia* Linnaeus attacking *G. extrematis*. In Illinois the host larvae of the latter are available throughout the year, and consequently the number of generations of *smithii* was determined by the duration of warm weather. Marsh observed five successive periods of adults' emergence. Adults palpated parasitized *S. cecropia* cocoons, pierced them and the *G. extrematis* cocoons they contained, and stung the parasite larvae. Since *smithii* has a short ovipositor, only those cocoons near the periphery of the *S. cecropia* cocoon could be reached. One egg (rarely two) was deposited in each parasite cocoon, and the stung host larva died within a few hours. The larva of *smithii* moved freely over the dead host, punctured the cuticle here and there, and fed on the juices. The period from egg to adult required about 18 days.

Garman (*1938*) reared *smithii* in Connecticut from trap bands removed from peach trees. Parasitization of the oriental fruit moth by *smithii* was 4.2 percent of all parasitism.

At the Moorestown laboratory *smithii* was rarely reared as a parasite from oriental fruit moth cocoons. In 1932 three cocoons collected at Evesboro, N.J., and one at Westfield, Mass., were parasitized

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by this species. The parasite overwintered in oriental fruit moth cocoons collected in late summer. Two were reared as primary parasites, which destroyed the host prepupae, and two as secondary parasites on undetermined primaries.

Mastrus carpocapsae (Cushman)

Mastrus carpocapsae has been reported by several workers as a primary parasite of *Carpocapsa pomonella*. It has also been reared from *Laspeyresia caryana* (Cushman *1917*) and *Melissopus latiferreanus* (Dohanian *1942*). It has been recorded by Stearns (*1928*) as a parasite of the oriental fruit moth in Pennsylvania. It has been recorded from New Jersey, Delaware, Kentucky, Nebraska, Illinois, Idaho, and California (Townes *1944*).

Considerable data on the biology of this species have been obtained. Flanders (*1926*) observed that the cocoons of *carpocapsae* were pure white. For 50 males, the period from egg to adult averaged 46 days. About 3 days were spent in the egg stage, 10 as feeding larvae, 8 to 35 as mature, resting larvae, 3 to 4 as prepupae, and 11 to 16 as pupae. In a battery jar 107 *C. pomonella* larvae in cocoons were stung by ovipositing females, but eggs were deposited on only 48.

McClure (*1933b*) observed that the female probed a *C. pomonella* cocoon with her ovipositor. When the larva was located, she stung and paralyzed it with a quick jab and laid one egg near the stinging puncture. The young larva rasped a hole in the cuticle and fed moderately until nearly full grown, when the entire contents were rapidly consumed. Two distinct sizes of male larvae were produced. The larger had a resting period, after completing its feeding, of 37 to 63 days; the smaller had a resting period of 2 to 7 days. He observed that without light the cocoons may remain white, but when exposed to light, they may turn within 1½ days from white to yellow, brown, and finally black. McClure (*1933a*) found that paralyzed cocooned larvae of *C. pomonella* which had been stung by *carpocapsae* remained immobilized, but they were alive and fresh, on an average, for 26 days and a maximum of 73. However, in some larvae, deterioration of tissue started within 2 days of stinging.

Lloyd (*1944*), who studied the biology of this species in California, did not observe the two types of life cycle described by McClure. Simonds (*1947*) was able to propagate this parasite successfully on *C. pomonella* larvae paralyzed by the ovipositing female and on hibernating larvae coddled 2 minutes in water at 125° F. In his work the period from egg to adult was 16 to 22 days. He was able to obtain an increase in the proportion of females to males after long, continued breeding.

Although *carpocapsae* might be expected to parasitize the oriental fruit moth, it was never reared from it at the Moorestown laboratory, and it has not been recorded from the oriental fruit moth by any workers since 1928.

Mastrus Sp.

Trap bands were removed on September 19, 1932, from an orchard at East Longmeadow, Mass., and the oriental fruit moths in them were overwintered at the Moorestown laboratory. The following spring four specimens of *Mastrus* sp. emerged. An examination of the host remains showed that two were primary parasites of oriental fruit moth prepupae and two were secondary parasites issuing from cocoons of *Glypta rufiscutellaris*.

Phobetes thyridopteryx (Riley)

Phobetes thyridopteryx was described more than 90 years ago, with illustrations of both sexes and of the habitat of the cocoon (Riley *1869*). Riley observed that there were five or six parasites per *Thyridopteryx ephemeraeformis* and that the cocoons formed in the host's pupal cases were tough and white. Despite the fact that this parasite has been frequently reared, some of the observations are contradictory. Little of its biology is known.

Although it has been rather frequently reared from the pupal cases of *T. ephemeraeformis*, some authors have considered it a primary parasite. Balduf (*1937*) pointed out that it could be parasitic on the larvae of the common ectoparasites of *T. ephemeraeformis* and this relationship would not readily be discovered. It is also probable that it may be both a primary and secondary parasite of *T. ephemeraeformis*, and in this dual relationship it may resemble several of the common hymenopterous parasites of the oriental fruit moth. Balduf observed two pupal cases with three cocoons in one and six in the other arranged as described by Riley, but the color was brown. He also found only females, although specimens from several places in Illinois were studied.

Shaffner and Griswold (*1934*) found only one parasite issuing from each *T. ephemeraeformis* pupal case. Viereck et al. (*1916*) considered it a parasite of *Itoplectis conquisitor* and *Iseropus coelebs* (Walsh). Townes (*in* Muesebeck et al. (*1951*)) stated that the distribution is transcontinental in the Upper and Lower Austral and Tropical Zones.

There are two published records of parasitism in the oriental fruit moth, one in Pennsylvania (Haeussler *1930*) and the other in western New York (Daniel et al. *1933*), with no supplemental information, even as to the stage of the host attacked. If *thyridopteryx* is ectoparasitic, as seems likely, it probably attacked the cocoon.

Genus GELIS

The genus *Gelis* has many North American species, several of which have been reared only from spider egg clusters. Three species have been reared as primary or secondary parasites of the oriental fruit moth.

KEY TO SPECIES OF GELIS ATTACKING ORIENTAL FRUIT MOTH COCOONS

1. Females winged 2
   Females wingless ..... *apantelis* Cush.
2. Wings without fuscous bands ..... *nocuus* Cush.
   Wings with fuscous bands ..... *tenellus* (Say)

Gelis tenellus (Say)

(Fig. 18)

Gelis tenellus is the only common ichneumonid parasite of oriental fruit moth cocoons. It has conspicuous fuscous bands on the forewing (fig. 18, *A*), is polyphagous, and is both a primary and a secondary parasite. Townes (*1944*) listed 39 recorded hosts, including 3 chrysopids, 13 Lepidoptera, 2 tenthredinids, 10 braconids, 6 ichneumonids, and 2 chalcidoids. Townes (*in* Muesebeck et al. (*1951*)) stated that in North America the distribution of *tenellus* is transcontinental in the Transitional and Upper and Lower Austral Zones. It occurs also in the Hawaiian Islands (Timberlake *1918*). The European species *Gelis areator* Panzer is taxonomically indistinguishable, but it differs in having both sexes and producing males parthenogenetically.

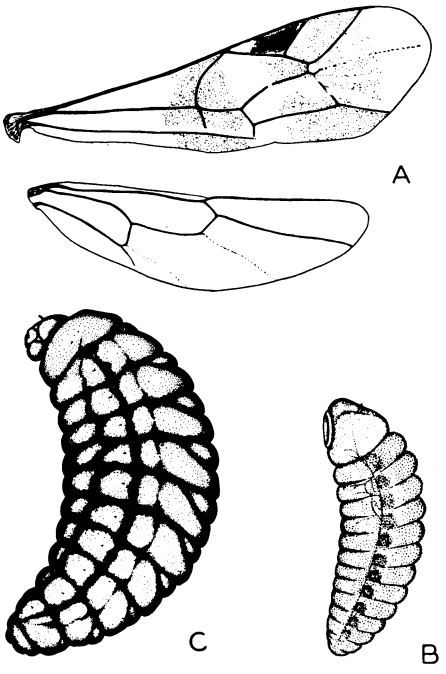

FIGURE 18.—*Gelis tenellus: A,* Wings; *B,* first-instar larva; *C,* mature larva. (*B* and *C* from Clancy (*1946a*).)

Muesebeck and Dohanian (*1927*) studied the life history of *tenellus* as a parasite of *Apanteles melanoscelus* (Ratzeburg). The relatively large eggs were deposited singly within the *Apanteles* cocoon but outside the body of the larva. Several might be deposited in one cocoon in separate attacks, but only one *Gelis* emerged from a cocoon. Adults usually laid 1 to 3 eggs per day; the largest number deposited by one female was 76. Adults pierced *Apanteles* larvae and fed on the exuding juices, sometimes leaving only shriveled remains. It was stated that the adults might live for several months. The egg hatched about 2 days after deposition, and the larval period was 6 or 7 days. The period from egg to adult averaged 22 days. This parasite hibernated as a full-grown larva in the cocoon of *Apanteles*. *G. tenellus* was easily reared in the laboratory. Only females were known and they were produced parthenogenetically. Twelve successive generations were reared without producing a single male. Doner (*1936*) stated that the egg was white, had a smooth shining chorion, and was 0.2 by 0.8 mm.

Clancy (*1946a*) studied the life cycle of *tenellus* in chrysopids and published illustrations of the larva (fig. 18) and pupa. His observations paralleled those of Muesebeck and Dohanian (*1927*). The egg had a delicately roughened chorion, with faint longitudinal ridges and small projections at each end. He observed that the adult, when excited, feigned death. Ovipositing females stung chrysopid larvae through their cocoons, producing paralysis in 2 to 20 minutes. The paralysis was permanent, though in some individuals it was not induced even after repeated stings. Paralysis persisted as long as 14 days. Large numbers of chrysopids were stung without subsequent oviposition, and the resulting mortality often exceeded normal parasitism. The egg was extruded at right angles to the ovipositor and a short distance up from the tip, so that when the ovipositor was withdrawn, the egg adhered to the inner wall of the cocoon. Clancy observed that feeding by *tenellus* adults was much less common on chrysopid larvae, prepupae, or pupae than on their primary parasites. Both first- and fifth-instar larvae had distinct head capsules, which were heavily sclerotized in the former, and both had distinct antennae. Larvae completed their development as ectoparasites, and after a quiescent period of several days they formed a delicate papery cocoon. The adult emerged through a round, jagged hole at one end of the cocoon.

G. tenellus has been recorded as a parasite of the oriental fruit moth in Connecticut (Garman *1930a*), New Jersey (Stearns *1928*, Haeussler *1930*, Brunson and Allen *1948*),

Virginia (Bobb *1942*), Ohio (Neiswander *1936*), and Ontario (Van Steenburgh *1938*). Haeussler, Neiswander, and Brunson and Allen each reported it as a primary and secondary parasite of the oriental fruit moth. Brunson (*1948*) found 3.1-percent parasitization of *Macrocentrus ancylivorus* cocoons in the oriental fruit moth in New Jersey in 1940 and 1.4-percent in 1945.

G. tenellus was reared only once (1932) at the Moorestown laboratory from oriental fruit moth cocoons collected in the field. However, it was reared frequently as a primary parasite from laboratory-reared cocoons exposed on peach trees in Burlington County, N.J., from 1931 to 1936, and once each from lots of cocoons exposed in Franklin County, Pa., and Rockingham County, Va. During these years it issued from 64 lots of cocoons, in which 6.6 percent of the 2,488 cocoons reared were parasitized by this species. The parasitization by *tenellus* in individual collections ranged up to 75 percent. In 83 specimens in which the examination of the host remains proved that the oriental fruit moth was the primary host, 52 *tenellus* parasites destroyed the prepupae and 31 the pupae. In 1932, 43 adults were reared as overwintering parasites of the egg clusters of gnaphosid spiders collected under the bark of peach trees at Moorestown. The parasites formed dingy-gray cocoons within the egg sacs. They issued through a round, ragged hole in the base of the sac—one adult from each egg sac. No males were ever reared at Moorestown.

In 1957 limited observations were made on the biology of *tenellus* as a parasite of the oriental fruit moth. Adults oviposited through the cardboard shelter of the host cocoons; they left small round holes readily detected by transmitted light. Host blood frequently exuded from the stabbed oriental fruit moth hosts and stained the paper about the ovipositor holes. Probably *tenellus* adults fed on this exuded blood.

There were several small experiments in breeding on oriental fruit moth prepupae and pupae. Only a few of the hosts exposed were parasitized. Parasitized prepupae were permanently paralyzed and an egg was loosely attached to the body. One or two days later an ectoparasitic larva hatched from the egg and became full grown 5 to 6 days after oviposition. Usually the tissues of the host were not completely consumed. Six to seven days after oviposition a thin-walled, parchmentlike white cocoon was spun, sometimes in the middle of the host cocoon beside its remains or at one end with the host remains in the opposite end. Pupae destroyed by this parasite were ruptured longitudinally. The adults emerged 16 to 18 days after oviposition, tearing away the ends of their cocoons. Some gnawed their way through the cardboard walls of the host cocoon and others through the soft silk at the end. A translucent molt skin of the last larval stage was found packed with the meconium, but no pupal exuvium was present.

Gelis apantelis Cushman

Nearly all the biological information published on *Gelis apantelis* was obtained by Muesebeck and Dohanian (*1927*). They studied it as a parasite of *Apanteles melanoscelus*. The eggs closely resembled those of *Gelis tenellus* and were deposited within the *Apanteles* cocoon on the larva. The period from egg to adult was about 18 days. The hibernating generation remained as full-grown larvae within the host cocoons from August until the following spring. The female was wingless and produced males when not fertilized. The males had wings.

This parasite has been reported only from Massachusetts.

Only one specimen of this species was reared at the Moorestown laboratory. It emerged as a primary parasite from the prepupa of the oriental fruit moth in a lot of insectary-reared cocoons exposed in a peach orchard at Ringgold, Md., in 1936.

Gelis nocuus Cushman

Two specimens of *Gelis nocuus* were reared as primary parasites of the oriental fruit moth at Moorestown, N.J. One issued from the pupa in a lot of insectary-reared cocoons exposed in June 1932 and the other from the prepupa in an overwintering cocoon collected in October 1932. The cocoon of one was thin and translucent white; the other was fuscous and more firmly constructed. Another specimen that was reared from oriental fruit moth cocoons collected at Olcott, N.Y., in 1932 was a secondary parasite issuing from the cocoon of a cremastinid parasite of the oriental fruit moth.

Cryptus albitarsis albitarsis (Say)

(Fig. 19)

The wing of the *Cryptus albitarsis albitarsis* adult differs from the wing of other ichneumonids attacking oriental fruit moth cocoons in the shape of the areolet and because the nervulus joins the median vein inside the basal vein (fig. 19).

Townes (*in* Muesebeck et al. (*1951*)) stated that *albitarsis albitarsis* occurs from the Atlantic Ocean to 100° W. in the Transitional and Upper Austral Zones. Although adults have been frequently collected in the field, only a few hosts—all Lepidoptera—have been recorded. Ashmead (*1897*)

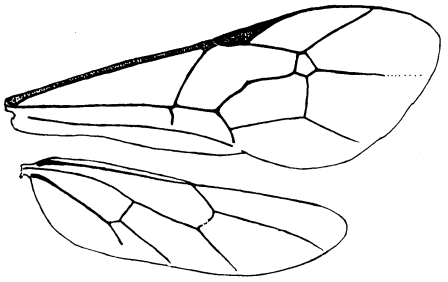

FIGURE 19.—Wings of *Cryptus albitarsis albitarsis.*

described specimens reared from *Psorosina hammondi* (Riley). Champlain (*1922*) stated that it was reared from *Sanninoidea exitiosa* (Say) in Pennsylvania, and Boyce (*1947b*) reported that it was a primary parasite of *Carpocapsa pomonella* in Ontario. It has been recorded as a parasite of the oriental fruit moth in New Jersey by Stearns (*1928*) and by Haeussler (*1930*), who observed that it attacked the cocoon.

At the Moorestown laboratory *albitarsis albitarsis* was occasionally reared as a primary parasite of the oriental fruit moth, but only from overwintering cocoons. One parasite emerged in April 1924 from a cocoon collected at Middletown, N.J. Three emerged from oriental fruit moth cocoons collected under bark at Bridgeboro, N.J., in March 1932. Two emerged in April 1932 from cocoons collected at Vincennes, Ind.

Gambrus ultimus (Cresson)

(Fig. 20)

Gambrus ultimus is a North American species. According to Townes (*in* Muesebeck et al. (*1951*)) it is transcontinentally distributed in the Upper and Lower Austral Zones of North America. Townes (*1947*) recorded that it was adventive in Hawaii. He (*in* Muesebeck et al. (*1951*)) listed nine

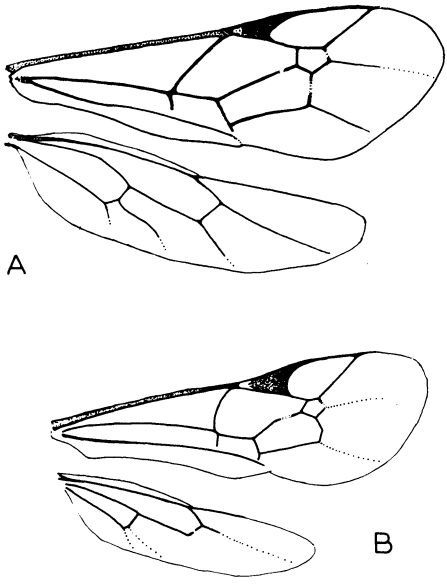

FIGURE 20.—*A*, Wings of *Gambrus ultimus; B*, wings of *Phaeogenes walshiae walshiae.*

hosts, all Lepidoptera, with a wide range of size and habit. They included casebearers, bagworms, leaf rollers, stem borers, and fruitworms. Hyperparasitism has not been recorded. Blickenstaff et al. (*1953*) reared several specimens from *Pyrausta nubilalis* in Iowa. Several authors reported rearing *ultimus* from *Ancylis comptana fragariae* on strawberry.

Balduf (*1929*) stated that in Illinois *ultimus* hibernated as a larva within its cocoon, which was deep brown and covered with fluffy silk. The cocoon was formed beside the remains of the primary host *Phlyctaenia tertialis* Guenée. Fink (*1932*) considered it the third most important parasite of *A. comptana fragariae* in New Jersey. He stated that the parasite oviposited within the host larva, but it issued from the pupa, spinning a white cocoon near the pupal remains. When it was reared from *A. comptana fragariae*, the pupal stage was 10 to 14 days.

G. ultimus has been reared frequently as a parasite of the oriental fruit moth (Stearns *1928*, Haeussler *1930*, McConnell *1932*, *1934*, Daniel *1932*, Merritt *1933b*, Garman *1938*, Brunson and Allen *1948*). It has been recorded from this host in Massachusetts, Connecticut, New York, New Jersey, Pennsylvania, and Maryland. Haeussler reared it from oriental fruit moth cocoons overwintering under quince bark; Merritt, Garman, and Brunson and Allen reared it from cocoons collected on peach trees; and McConnell reared it from cocoons collected from harvested peaches.

In 1931 and 1932 at the Moorestown laboratory *ultimus* was reared from oriental fruit moth cocoons collected in peach orchards in the following counties: Hampden, Mass., Tolland, Conn., Burlington, N.J., and York, Pa. In 1934 it was reared from laboratory-bred cocoons exposed in peach orchards. In the 17 lots from which *ultimus* was reared, the parasitization by this species was 3.7 percent of the 1,433 total insects reared. The highest rate in any lot was 26 percent.

At the Moorestown laboratory *ultimus* was never reared as a secondary parasite, and it occurred as a parasite of both transforming and overwintering generations. In the transforming generations most of the specimens examined had attacked and issued from pupae, whereas in the hibernating generation *ultimus* issued from prepupae. Seventy percent of the adults reared from the oriental fruit moth were females. In laboratory tests parasite adults obtained from *A. comptana fragariae* readily parasitized the oriental fruit moth. Oriental fruit moth cocoons were attacked in the usual manner. One to several large ovipositor holes were readily visible through the cardboard covering of each cocoon attacked. The

preovipositional period was not over 2 days. When oriental fruit moth larvae were attacked, they were permanently paralyzed, and one to four eggs were attached externally to the paralyzed body. The larva was ectoparasitic and completed its development in only 6 to 7 days after oviposition.

The full-grown larva was almost lemon yellow, with a well-differentiated white head on which there were small antennae. The thorax was finely roughened and the abdomen longitudinally creased. The cuticle was rather opaque, but subcuticular white flecks were faintly visible. The cocoon was formed beside the prepupal remains or embedded in the fragments of the pupa. It was thin, white, obscurely ovoid, and with or without surrounding woolly threads. In the hibernating generation the wall was usually thicker and dingy gray.

The entire developmental period from oviposition to emergence was only 10 to 13 days. The emerging parasite cast a thin, nearly transparent pupal pellicle, which was found packed with the meconium. It tore away the entire end of its cocoon and chewed up the host debris that blocked its exit. This mixture of silk and sclerotized fragments of host pupal cases or prepupal skins was left as a conspicuous ball in the cocoon from which the parasite emerged. It may emerge from either end of the host cocoon, and it usually cut a round exit hole through the cardboard cover of the cocoon.

Lymeon orbum (Say)

(Fig. 21)

The adult of *Lymeon orbum* differs from that of other species attacking oriental fruit moth cocoons in having the areolet small and open toward the wingtip and the nervulus joining the median vein mediad of the basal vein (fig. 21, *A*).

Comparatively little has been published on the hosts and biology of this brilliantly marked ichneumonid during the 120 years since it was first described. Cushman (*1929*) listed *orbum* as a parasite of spider egg sacs, of the oriental fruit moth, and of a casebearer on smartweed (*Polygonum*). Creighton (*1937*) recorded it as a parasite of a cosmopterygid leaf miner of palms. Townes (*1944*) stated that it is distributed from Maryland to Florida and westward to Illinois and Texas. There is little published information on *orbum* as a parasite of the oriental fruit moth. Haeussler (*1930*) listed it as a parasite of the oriental fruit moth in Virginia. Brunson and Allen (*1948*) observed that it usually occurred as a primary parasite when reared from oriental fruit moth cocoons.

At the Moorestown laboratory *orbum* was reared twice from gnaphosid egg sacs collected on January 25, 1932. It formed a thin-walled white cocoon within these sacs and issued through the thin silk base. It was also reared once from field-collected oriental fruit moth cocoons, and then it was a secondary parasite. It was a common primary parasite in laboratory-reared cocoons exposed in peach orchards in Burlington County, N.J., and in Rockingham and Roanoke Counties, Va. In 1957 it was reared from cocoons exposed in an abandoned apple orchard, in woodlots, and in an open weedy field bordering a woodland. Over a period of several years the host remains of 100 oriental fruit moth cocoons from which this parasite was reared were examined. *L. orbum* issued from pupae in 77 and prepupae in 23 host cocoons. In the Moorestown collection there are 52 females and 38 males that emerged

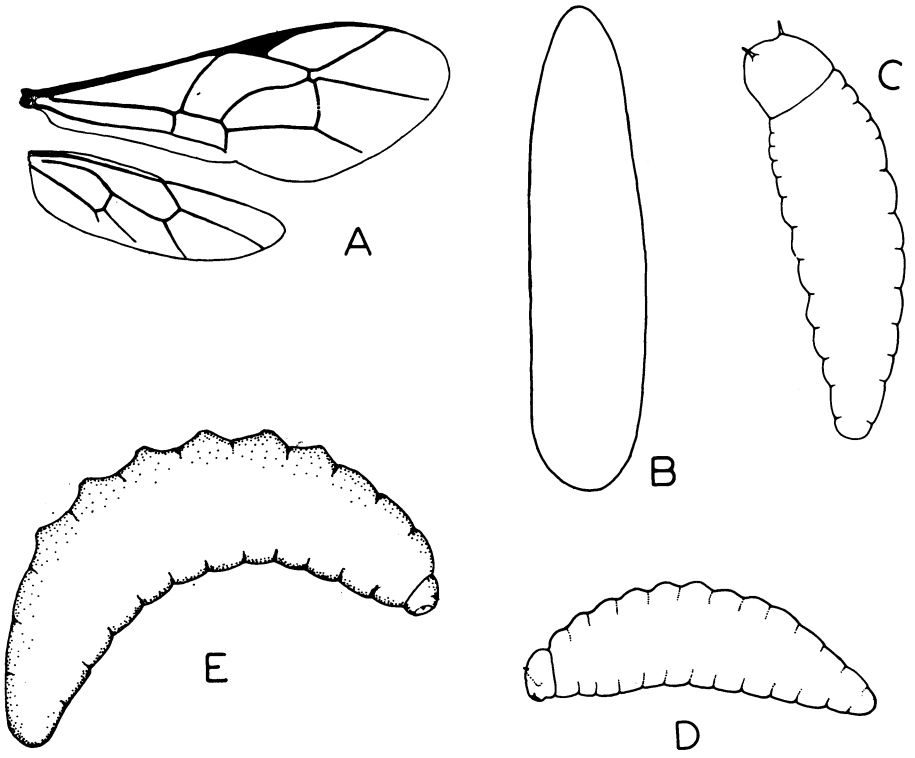

FIGURE 21.—*Lymeon orbum: A*, Wings; *B*, egg; *C*, first-instar larva; *D*, half-grown larva; *E*, full-grown larva.

from the oriental fruit moth. In 1957 *orbum* was reared only as a primary parasite, although some of the cocoons exposed contained *Macrocentrus ancylivorus*. From 1931 to 1936 *orbum* was reared from 27 lots of oriental fruit moth cocoons, from which a total of 1,336 insects were reared. The maximum parasitization by this parasite in any lot was 60.0 percent and the average 7.6 percent.

L. orbum was propagated by exposing oriental fruit moth cocoons containing young pupae to parasites in glass breeding tubes. Females oviposited through the cardboard of the cocoon shelter; they left relatively large round holes, usually several for each cocoon attacked. They also pierced and probed many individuals until the area about the wound was wet with blood. They then fed on the exuding juices. Numerous pupae used thus for a blood meal were permanently paralyzed but were not parasitized. One was still well preserved 11 days after being paralyzed, but many died soon after being bled by adult parasites. Evidently this species kills many more hosts than those from which progeny are reared.

In the breeding experiment at the Moorestown laboratory no eggs were obtained until 4 days after emergence. The females that were used lived for more than a month and remained reproductive for 35 days until the experiment was terminated before they died. The ovipositing female paralyzed the host and deposited, loosely attached to its body, a beautiful pale-green egg (fig. 21, *B*), which was 1.3 by 0.3 mm. Either pupae or prepupae were readily parasitized, and one to several black sclerotized sting

marks, randomly distributed in the middle of the host, were visible.

The eggs hatched on the first or second day after oviposition. Usually there was only one young larva on each host. This larva was active and moved freely about over the body of the host, frequently standing erect. The newly hatched larva (fig. 21, *C*) was 1.3 mm. long, was translucent white with a yellowish digestive tract, and had a subcuticular belt of widely separated white flecks on the abdomen. When pupae were the hosts, the young parasite larva depressed the abdominal wall and worked its anterior end under the lower edge of the wing pads. From this position it proceeded to clean out all the soft tissues, which remained fresh until consumed. The mature larvae, which completed their feeding about 4 days after oviposition, ranged from 5.0 to 5.8 mm. long and 1.3 to 1.5 mm. broad. The full-grown larva (fig. 21, *E*) had small conical antennae and five conspicuous, truncate, transverse dorsal ridges.

Cocoons were completed as early as 5 days after oviposition. They were thin, white, and parchment-like. When pupae were parasitized, the cocoons protruded from the host pupal cases or were embedded in pupal fragments. When the hosts were prepupae, the completely cleaned larval skin was usually left at one end of the cocoon cavity, and the parasite cocoon occupied the other end.

The emerging parasites tore away the end of their cocoons and usually issued from holes gnawed through the cardboard walls of the cocoon shelters. The cast skin of the mature larva, but no pupal exuvium, was found with the meconial debris. Adults emerged 12 to 18 days after oviposition, the largest number within 14 to 15 days. In host material parasitized from July 23 to September 6 by 4 unmated females, 49 males were reared and no females. There were no hibernating individuals or delayed emergence.

Phaeogenes walshiae walshiae (Ashmead)

(Figs. 20 and 22)

The wing of *Phaeogenes walshiae walshiae* may be distinguished from that of other ichneumonids that attack oriental fruit moth cocoons by the relatively large areolet (fig. 20, *B*), which is closed on the outside and is only a short distance from the stigma. The female has a slightly clavate antenna (fig. 22, *B*) and a well-sheathed ovipositor (fig. 22, *C*), which distinguish her from the male.

This species has been reported as a primary parasite of four species of Lepidoptera. It was reared about 1896 from the momphid *Walshia amorphella* in Illinois (Ashmead *1896*) and from 1931 to 1934 as a pupal parasite of *Ancylis comptana fragariae* and *Epiblema strenuana* in Delaware (Haden *1935*).

It has been most frequently reported as a parasite of the oriental fruit moth. It was first reared from this host in 1918 (Wood and Selkregg *1918*) as a pupal parasite, and it was the second most common parasite on the oriental fruit moth in the vicinity of Washington, D.C. Since then it has been reported as a parasite of the oriental fruit moth in New Jersey, Pennsylvania, Virginia, Ohio, Maryland, and Delaware (Stearns *1928*, Haeussler *1930*, Stearns and Neiswander *1930*, Neiswander *1936*, McConnell *1932*, Haden *1935*, Brunson and Allen *1948*). It has not been reported from either the northern or southern sections of the United States where peaches are grown. Several authors noted that it was a pupal

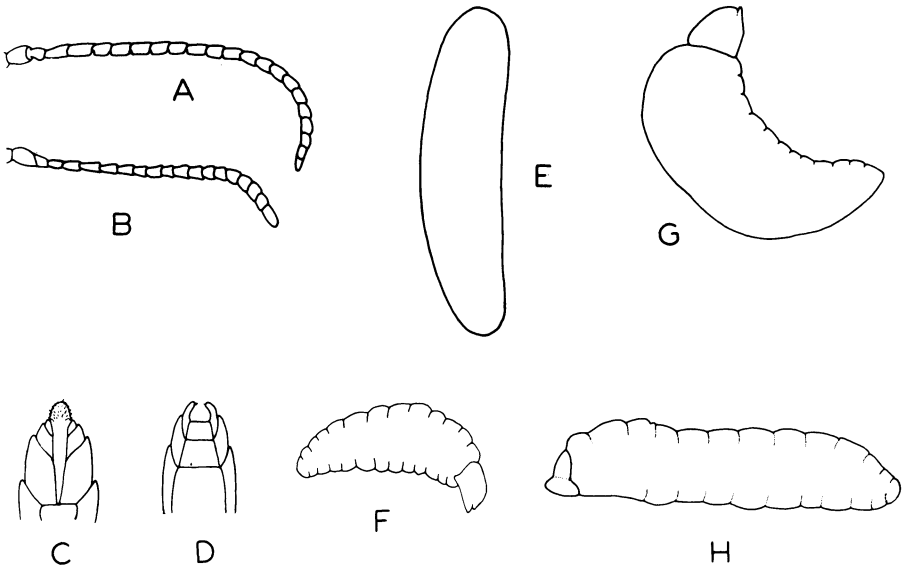

FIGURE 22.—*Phaeogenes walshiae walshiae: A*, Antenna of adult male; *B*, antenna of female; *C*, ventral view of abdomen of female; *D*, ventral view of abdomen of male; *E*, egg; *F*, newly hatched first-instar larva; *G*, partly developed first-instar larva; *H*, full-grown larva.

parasite of the oriental fruit moth. Haeussler observed that it was an internal parasite, and he reared it from cocoons collected under quince bark. Haden found it the most important oriental fruit moth parasite of the third generation. He reared it from cocoons collected from harvested peaches.

At the Moorestown laboratory it was most frequently reared as a parasite of laboratory-bred oriental fruit moth cocoons exposed in peach orchards, but in 1936 it was also reared from cocoons exposed in a neglected apple orchard. It was never reared as a secondary parasite. Parasitism in oriental fruit moth cocoons occurred in all months from May through September. Of the 60 specimens in the Moorestown collection that were reared from the oriental fruit moth, 75 percent were females. From the 38 lots of cocoons exposed in Burlington County, N.J., from which this parasite was reared from 1931 to 1936, the total emergence was 2,093 parasites and the average parasitization by *walshiae walshiae* was 8.4 percent. The highest parasitization in any lot was 31.8 percent. At Moorestown several were reared in 1930 from first-generation galls of *E. strenuana*.

The adults of *walshiae walshiae* fly freely and are also agile runners, darting about like ants. Unlike most cocoon parasites of the oriental fruit moth they do not oviposit through the cocoon shelter, but tear a hole through the soft silk at the anterior end of the cocoon and crawl into it to oviposit. The oviposition scars persist as small round black spots on the pupal case. The pupa may be pierced at nearly any point but most frequently at the extreme end. There was no evidence that adults fed on the blood of their victims. Only pupae were attacked, and these were not paralyzed by the adult parasites. Usually one egg was deposited in each host. This lay free in the semifluid host tissue. The egg (fig.

22, *E*) was elongate, slightly curved, translucent, and smoothly glistening without apparent sculpturing. It was about 0.86 by 0.17 mm.

A larva (fig. 22, *F*) hatched from the egg 1 or 2 days after it was laid. The larva had two fleshy palps in the labial region, a yellow intestine, and a conically pointed caudal segment. It soon became humpbacked (fig. 22, *G*) and embedded in a viscous lump of tissue, which adhered tenaciously to it. Two or three days after oviposition the parasite larva became firmly footed in the posterior end of the host pupa. From this position it consumed all the remaining soft tissues, which stayed fresh until feeding was completed. Larvae reached maturity 5 to 6 days after oviposition. At this period they were extremely active and could flex the segments of the cleaned-out and distended host pupal cases enough to roll them over flat surfaces. The full-grown larva (fig. 22, *H*) had a small head with no apparent antennae, but with the labial region conspicuously protruding. The thorax was sometimes lemon yellow. The posterior end was conical, and there were conspicuous lateral callosities.

This parasite pupated in the host pupal case without forming a cocoon. Pupation may begin 7 to 8 days after oviposition. Parasite pupae were oriented with their heads in the anterior end of the host cocoon. They emerged by tearing away the anterior end of the host pupal case and pushing out through the end of the cocoon, which had been ruptured several days earlier by the ovipositing parent. Adults emerged 12 to 17 days after the eggs were deposited, most within 13 to 14 days.

The remains of *walshiae walshiae* in the host cocoon differed only slightly from those of *Pimpla inflata* and *Itoplectis conquisitor*. The host pupal case left by *walshiae walshiae* had an emergence hole that was perceptibly ventral, and the meconial remains were brown and scattered. In *P. inflata* the entire anterior end was torn away, and the meconium was black and pressed into the extreme posterior end. In *I. conquisitor* there was usually a narrow horn of the pupal case extending over the exit hole, and although the meconium was scattered, it was black.

P. walshiae walshiae was readily propagated on the oriental fruit moth in glass vials or in small wooden cages. In one experiment three mated females were kept in a wooden cage with food and water and supplied at frequent intervals with oriental fruit moth cocoons containing newly formed pupae. Breeding was from July 30 to September 6, when it was terminated before the females died. These females produced 87 females and 233 males; the rate of increase of females was twenty-ninefold. The breeding females remained reproductive for the 38 days they were kept in the breeding cage, but their daily rate of effective parasitization gradually decreased from an initial six pupae per female per day to less than one per day. The average number of oriental fruit moth pupae parasitized by each *walshiae walshiae* female was 106. Although males usually exceeded females in the laboratory breeding, a satisfactory increase in female progeny was maintained for three successive generations.

Chalcidoidea

KEY TO FAMILIES OF CHALCIDOIDEA ATTACKING ORIENTAL FRUIT MOTH COCOONS

1. Tarsus 5-jointed; foretibia armed with large curved spur; antenna with 10 or more joints 2
   Tarsus 4-jointed; foretibia with delicate, short, straight spur; antenna 8- or 9-jointed ..... *Eulophidae* (*Syntomosphyrum*)
2. Hindfemur not greatly enlarged 3
   Hindfemur much swollen ..... *Chalcididae* (*Brachymeria, Haltichella, Spilochalcis*)
3. Pronotum small, frequently not visible in middle 5
   Pronotum large 4
4. Body not metallic; posterior femur without prominent apical tooth *Eurytomidae* (*Eurytoma*)
   Body metallic; posterior femur with prominent tooth distally *Torymidae* (*Monodontomerus*)
5. Midlegs of female long and saltatorial, with very long tibial spur and with first tarsal joint swollen *Eupelmidae* (*Eupelmus, Encyrtaspis, Arachnophaga, Eupelmella*)
   Midlegs not saltatorial; first tarsal joint not swollen *Pteromalidae* (*Tritneptis, Dibrachys*)

EULOPHIDAE

Syntomosphyrum esurus (Riley)

(Fig. 23)

Syntomosphyrum esurus has been reared from several common pests since it was first described in 1879, but comparatively little is known of its biology. Several workers reported that it is a parasite of the pupae of *Alabama argillacea*. Howard (*1897*) published an illustration of the adult (fig. 23), reviewed early literature, and reported rearing it from pupae of *Hyphantria cunea* (Drury), but he suspected

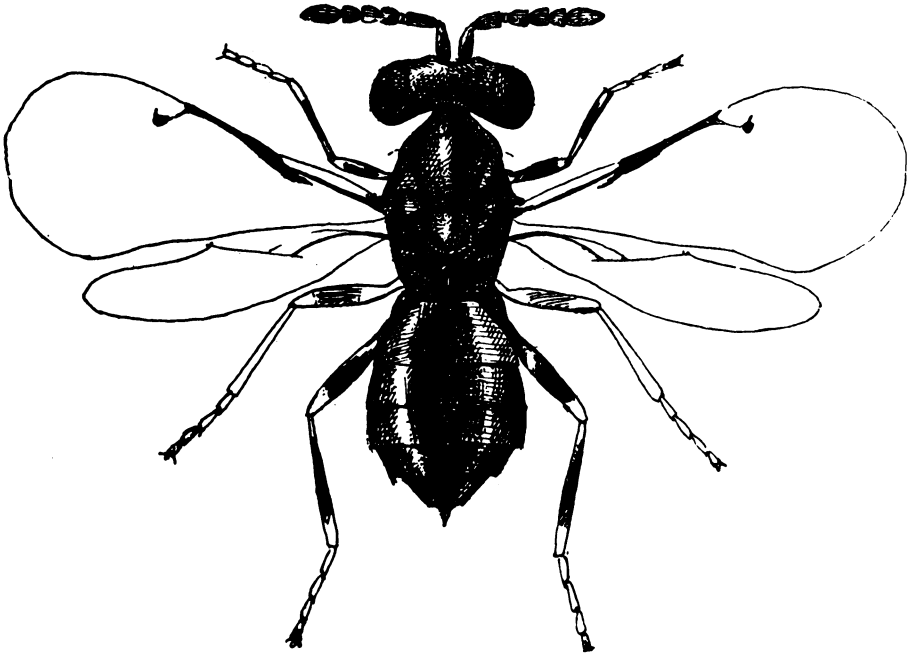

FIGURE 23.—Adult of *Syntomosphyrum esurus*. (From Howard (*1897*).)

that it was always a hyperparasite. Muesebeck et al. (*1951*) noted its distribution in New Brunswick, Connecticut, New Jersey, Pennsylvania, District of Columbia, West Virginia, Georgia, Alabama, and Texas. Their list of hosts includes nine Lepidoptera, among which are several of the commonest defoliating caterpillars. It has never been reported as a hyperparasite. Several authors observed that it is a parasite of the pupa and that many individuals issue from one pupa. Howard noted that on *A. argillacea* in the Deep South the adults emerged in the fall and spring and even on warm winter days. Howard and Fiske (*1911*) reared it from *Nygmia phaeorrhoea* (Donovan) in New England in 1906 and in 1910, but not in the intervening years.

It has been reported several times as a pupal parasite of the oriental fruit moth in New Jersey (Driggers *1929*, Haeussler *1930*, Driggers *1931*, Brunson and Allen *1948*). Driggers reared it in the laboratory for several generations and found that it parasitized pupae, that the period from egg to adult was about 18 days, that 5 to 45 adults emerged from each pupa, and that it overwintered in the oriental fruit moth, from which it started to emerge the first week in May.

S. esurus was never reared at the Moorestown laboratory from oriental fruit moths collected in the field. In parasite-free oriental fruit moth cocoons exposed in peach orchards each year from 1931 to 1936, it was reared only in 1932 and 1934. Cocoons were attacked by this parasite from late June to early September, and in the 10 collections from which it was reared 5.0 percent of the cocoons were parasitized. In the 16 instances where host remains were examined, *esurus* was a primary parasite of the oriental fruit moth and emerged from the pupa.

EUPELMIDAE

The eupelmid parasites of the oriental fruit moth, like all Chalcidoidea, have greatly reduced wing venation in the adults. Females have a midleg that is conspicuously saltatorial, with a long tibial spur and a swollen first tarsal joint. Several of the species may be either primary or secondary parasites of the oriental fruit moth, but the commoner ones are more frequently primaries.

KEY TO GENERA OF EUPELMIDAE ATTACKING ORIENTAL FRUIT MOTH COCOONS

1. Eyes more or less pubescent, at least in female; posterior tibia strongly compressed 3
   Eyes not pubescent; posterior tibia not compressed 2
2. Wings much reduced, nonfunctional ..... *Eupelmella*
   Wings normal ..... *Eupelmus*
3. Posterior margin of hindtibia expanded in thin yellow carina; female with long black hairs on middle of scutellum ..... *Encyrtaspis*
   Posterior margin of hindtibia never with thin yellow border; female without hairs on scutellum ..... *Arachnophaga*

Genus EUPELMUS

Five species and subspecies of *Eupelmus* have been reared as primary or secondary parasites of the oriental fruit moth. The adults are small elongate chalcidoids with a slender thorax and with metallic green or blue on the head and thorax. The wings are functional. In the females the basitarsus of the middle leg is enlarged and the hindtibia is not compressed. The males differ conspicuously from the females.

KEY TO FEMALES OF EUPELMUS ATTACKING ORIENTAL FRUIT MOTH COCOONS

1. Ovipositor long, in repose extending nearly half length of abdomen beyond its tip 3
   Ovipositor short, in repose extending only slightly beyond tip of abdomen 2
2. Anterior femur entirely dark brown or black ..... *allynii* (French)
   Anterior femur yellow with small metallic green streak on outer surface ..... *limneriae* How.
3. Pedicel of antenna less than twice as long as greatest width; scape not conspicuously carinate; sculpturing of face coarsely shallow punctate 4
   Pedicel of antenna at least twice as long as greatest width; scape sharply and conspicuously carinate; sculpturing of face relatively weak ..... *spongipartus* Foerst.
4. Apical half of ovipositor brown ..... *cyaniceps cyaniceps* Ashm.
   Apical three-fourths of ovipositor brown ..... *cyaniceps amicus* Gir.

Eupelmus limneriae Howard

(Figs. 24 and 25)

The first record of *Eupelmus limneriae* is as a secondary parasite of *Hemerocampa leucostigma* (J. E. Smith) issuing from an ichneumonid primary. Howard (*1897*) published an illustration of the adult (fig. 24). Muesebeck et al. (*1951*) recorded it as a parasite of *Homaledra sabalella* (Chambers), *Campoplex validus* (Cresson), *Ceratosmicra debilis* (Say), and an undetermined *Macrocentrus*. They reported its distribution in Connecticut, District of Columbia, North Carolina, and Florida. Although the hosts listed seem to indicate that it occurs frequently as a secondary parasite, it has been reared as a primary parasite of the oriental fruit moth in South Carolina (Eddy and Nettles *1931*), Maryland (McConnell *1932*), and New Jersey (Brunson *1957*). Nettles (*1934*) observed that 6.8 percent of all the parasites reared from oriental fruit moth pupae collected from fruits and spurs of peaches in 1932 were *limneriae* parasites.

Prior to 1956 *limneriae* was reared only twice from the oriental

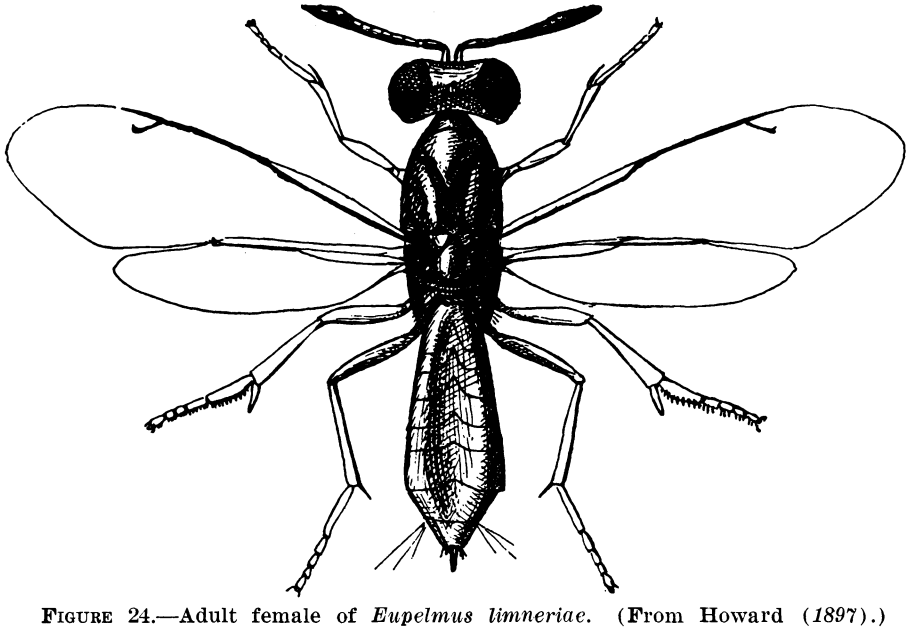

FIGURE 24.—Adult female of *Eupelmus limneriae*. (From Howard (*1897*).)

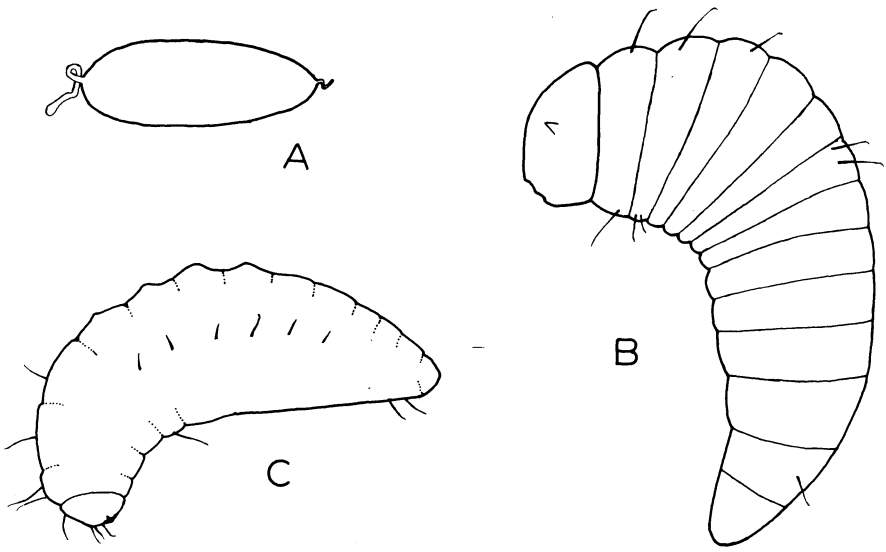

FIGURE 25.—*Eupelmus limneriae: A*, Egg; *B*, first-instar larva; *C*, full-grown larva.

fruit moth at the Moorestown laboratory. In 1956 *limneriae* was the only *Eupelmus* species reared frequently from oriental fruit moth cocoons. The 22 specimens reared were all females. They were obtained from several localities in Burlington County, N.J., and comprised 5 percent of the parasites reared from oriental fruit moth cocoons. In 1957 *limneriae* was again a common parasite of oriental fruit moth cocoons in Burlington County. Most of the *limneriae* specimens reared from cocoons exposed in orchards issued from pupae and prepupae of the oriental fruit moth, but when *Macrocentrus ancylivorus* was present as a primary parasite, it was also attacked. Only females issued from the field-exposed cocoons. All but one of the recoveries were from lots exposed between May 13 and July 15. In the lots where it occurred *limneriae* was a common parasite.

E. limneriae was readily propagated when adults in glass tubes were provided with food and water and suitable host material. The adults were active jumpers and could hop several inches. They also flew several feet but did not do so freely. When exposed with oriental fruit moth cocoons in cardboard shelters, they oviposited through the paper. *E. limneriae* heavily parasitized *Macrocentrus* cocoons when they were exposed, but only a few of the oriental fruit moth cocoons exposed were also successfully parasitized. In breeding cages unsuccessful parasitism of oriental fruit moth prepupae was common, and many times dead parasite larvae were observed beside the dried bodies of hosts, which had died prematurely. The attacks on oriental fruit moth pupae and the prepupae or pupae of *M. ancylivorus* were usually successful. Some of the females used in propagation tests lived for a month or more and remained reproductive throughout this period.

The egg (fig. 25, *A*) was 0.46 by 0.17 mm. and had a twisted pedicel and filament and an unsculptured chorion. Eggs were found lying loosely on their sides on the inner

walls of oriental fruit moth cocoons or adhering loosely to the hosts. In one cocoon containing an oriental fruit moth pupa, two eggs were discovered in a loose web on the inner wall of the cocoon. When eggs were deposited in cocoons containing oriental fruit moth prepupae, the prepupae were paralyzed at oviposition; when deposited in cocoons containing pupae, some were paralyzed but several were not. When *M. ancylivorus* cocoons were attacked, the eggs were deposited within the parasite cocoon. This was accomplished apparently by ovipositing through the cardboard wall of the host cocoon and the silken wall of the parasite cocoon. Two or more eggs were frequently deposited in the cocoon of a single individual. About 1 day after oviposition the eggs hatched and the young larvae (fig. 25, *B*) started feeding as ectoparasites.

The developing larvae were able to loop about over the body of the host, but they were usually relatively inactive and fed through numerous punctures in the middle section of the host. The darkened area of tissue first noted there gradually spread over the entire body of the host. Feeding was completed about 8 to 9 days after oviposition. The mature larva (fig. 25, *C*) was robust and muddy gray, lacked conspicuous antennae, but had long, sparse, wavy hairs. It averaged 2.8 by 1.0 mm. Feeding was completed without entirely consuming the soft tissues of the host. When oriental fruit moth pupae were attacked, the larvae usually fed by depressing the ventral wall of the pupa below the wing pads. Several larvae frequently started to develop on one host, but only one matured.

The pupae were formed beside the host remains. They were stout, rigid, and dull black. The emerging parasites left conspicuous fragments of the heavy black pupal cases in parasitized cocoons beside the remains of their hosts. *E. limneriae* appeared to issue from *M. ancylivorus* cocoons at nearly any point, and when this was adjacent to the cocoon wall of the primary host, it cut its way out at that point. Emergence from oriental fruit moth cocoons was frequently through the soft silk at the end of the cocoon. The exit hole was fringed with gnawed-off fragments of cocoon.

Host material was exposed to *limneriae* in small lots and was changed daily from June 10 to September 6. There was no hibernation among the parasites reared. In the breeding lots in which unmated females were used there were 64 adult progeny, of which 17 percent were females. In two small breeding lots in which males were present with breeding females, one-third of the progeny were females. The period from oviposition to emergence ranged from 15 to 23 days, but the largest number of males emerged 17 days and females 20 days after oviposition.

Eupelmus spongipartus Foerster

Eupelmus spongipartus occurs in Europe and North America. Muesebeck et al. (*1951*) stated that it occurs in New York, Connecticut, Pennsylvania, Maryland, and Ohio and is parasitic on *Apanteles melanoscelus*, *Macrocentrus ancylivorus*, and *Meteorus versicolor* (Wesmael). Muesebeck and Dohanian (*1927*) found that in *A. melanoscelus* one to several eggs were deposited by *spongipartus* within the cocoon, sometimes on a larva, but more frequently they were attached to the inner wall by a delicate fibrous net. They observed that only one parasite matured in a cocoon and that in New England there was usually only one full generation annually in *A. melanoscelus*.

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The overwintering individuals spent nearly 11 months as mature larvae within the host cocoons. There was also a partial generation of transforming individuals, which required 25 to 38 days to develop from egg to adult. The time spent in the various stages was 3 to 4 days as eggs, 15 days as larvae passing through five instars, and 12 to 14 days as pupae. Unfertilized females oviposited readily and their progeny were all males. Brunson and Allen (*1948*) reported that *spongipartus* was a primary and secondary parasite of cocooned oriental fruit moths.

E. spongipartus was reared more frequently from oriental fruit moth cocoons at the Moorestown laboratory than any of the other 10 species of Eupelmidae. It occurred sometimes as a primary parasite of this host but more frequently as a secondary. In 1932, 33 *spongipartus* specimens were reared from cocoons of this host in collections from the following counties: Hartford, Conn., Chautauqua, Niagara, and Orleans, N.Y., Lancaster, Washington, and York, Pa., Washington, Md., Frederick, Va., and Ottawa, Ohio. An examination of the host remains revealed that 15 *spongipartus* parasites issued from *Glypta rufiscutellaris*, 5 from *Macrocentrus ancylivorus*, 1 probably from *M. delicatus*, 1 from *Temelucha minor*, and 10 from undetermined parasites, all from the cocoons of primary parasites of the oriental fruit moth located within its cocoon. Only one issued as a primary parasite of the pupa of this host.

In parasite-free oriental fruit moth cocoons exposed in peach orchards in Burlington County, N.J., from 1931 to 1936, *spongipartus* was reared from 26 collections as a primary parasite. In these collections 31 *spongipartus* specimens were reared from 1,389 host cocoons. The rate of parasitization was 2.2 percent. Seventy percent of those reared as primary parasites killed the prepupa and the remainder destroyed the pupa. Adults that emerged from *Glypta* and *Macrocentrus* cut a large ragged hole near the end of the cocoon. The remains of parasitized oriental fruit moth pupae were broadly ruptured longitudinally. Among adults emerging from cocoons of this host collected or exposed in the field, 88 percent were females.

Eupelmus cyaniceps cyaniceps Ashmead

Pierce et al. (*1912*) recorded 18 hosts of *Eupelmus cyaniceps cyaniceps*, principally curculionids and including *Anthonomus grandis*. Muesebeck et al. (*1951*) stated that it occurs from Ontario to Florida, and in Mississippi, Louisiana, Texas, Arkansas, Oklahoma, Kansas, and New Mexico. They listed 27 hosts, principally curculionids, but also including 2 braconids and 4 Lepidoptera—oriental fruit moth, *Carpocapsa pomonella*, *Thyridopteryx ephemeraeformis*, and *Bucculatrix fuscicola* Braun. It has also been reared from *Gnorimoschema baccharisella* Busck in California (Tilden *1951*).

The principal observations on its biology are recorded by Pierce (*1908*) and Pierce et al. (*1912*). They found that it was a common primary parasite of weevils living in buds and stems and was also occasionally a secondary attacking the primary parasites of the weevil host. They noted that the egg had a pedicel, that either the larva or the pupa of *A. grandis* may be parasitized, that the development period in August was more than 26 days, that the cast exuvium of the pupa is brown, and that about 20 percent of the adults examined were males.

According to B. D. Burks at the U.S. National Museum, material in

the U.S. National Museum labeled "ex. *L. molesta*" includes one specimen, August 23, 1932, from Clemson, S.C., (W. C. Nettles), and another from the same locality, April–May 1934. Of 16 specimens in the second series, only 1 has a host label, but all are presumably from the oriental fruit moth.

In the parasite studies at the Moorestown laboratory *cyaniceps cyaniceps* was not found associated with the oriental fruit moth until 1956, when three were reared as primary parasites of oriental fruit moth cocoons (Brunson *1957*). In 1930 several were reared from galls of first-generation *Epiblema strenuana* collected at Moorestown and others from Grasonville, Md., and Greenfield, Ohio. Some of these may have been primary parasites, but others were secondaries, issuing from cocoons of *Macrocentrus* and other unidentified species. Another *cyaniceps cyaniceps* was reared after it overwintered in a stem of evening-primrose infested by *Mompha eloisella* collected in October at New Brunswick, N.J.

Eupelmus cyaniceps amicus Girault

Eupelmus cyaniceps amicus is a relatively common North American parasite of Coleoptera and Lepidoptera, whose larvae live in galls, cells, or tunnels in plant stems, and of their parasites. Muesebeck et al. (*1951*) stated that it occurs from New York to Georgia and Illinois and in Arkansas and New Mexico. Their list of hosts includes eight Coleoptera (bruchids, curculionids, and scolytids), four Lepidoptera (olethreutids and coleophorids), and one Hymenoptera (braconid). It has also been reared from *Thyridopteryx ephemeraeformis* (Balduf *1937*), *Epiblema strenuana* (Cartwright *1935*), and *Acrobasis caryae* and several of its braconid, ichneumonid, and bethylid parasites, including *Brachymeria hammari* (Crawford), *Calliephialtes graphololithae*, and *Macrocentrus instabilis* (Nickels et al. *1950*).

E. cyaniceps amicus has been recorded by several workers as a primary or secondary parasite of the oriental fruit moth. Driggers (*1930b*) found it in New Jersey parasitizing a large number of the *Glypta* cocoons that had overwintered in cocoons of the oriental fruit moth. Haeussler (*1930*) noted that it was a secondary parasite of the oriental fruit moth in Virginia. It was also reported by Stearns and Neiswander (*1930*) as a parasite of the oriental fruit moth in Ohio and by McConnell (*1932*) in Maryland. Nettles (*1934*) reared it as a primary parasite of oriental fruit moth pupae collected on peach trees in South Carolina and Brunson (*1948*) as a parasite of *Macrocentrus ancylivorus* in oriental fruit moth cocoons.

In surveys of cocoon parasitism made by the Moorestown laboratory from 1931 to 1936, *cyaniceps amicus* was never abundant, and it occurred as a primary only when the usual primary parasites were not present. It was reared as a primary parasite from four lots of parasite-free oriental fruit moth cocoons exposed in peach orchards. In cocoons collected from peach orchards in Mercer and Monmouth Counties, N.J., and in Erie and Ottawa Counties, Ohio, that contained primary parasites, 10 *cyaniceps amicus* adults were reared, all as secondary parasites issuing from cocoons of *M. ancylivorus*. The adults issued through a round hole, which was cut in the side of the cocoon near one end and through which the light-brown fragments of the *cyaniceps amicus* pupa were plainly visible.

Twenty-five percent or more of the adults reared by Beacher (*1947*)

from *Coleophora malivorella* were males, but Nickels et al. (*1950*) reared only females from *A. caryae* and its parasites. In the collections at the Moorestown laboratory of specimens reared from the oriental fruit moth and *M. ancylivorus*, there are nine females and three males.

Eupelmus allynii (French)

Eupelmus allynii has been more frequently mentioned in the literature than any other North American species of the genus. It has been studied principally as a parasite of the pests of wheat. Presumably its life history closely parallels that of other species of *Eupelmus*. It appears to have been recognized as early as 1862, and there are several early references to it as a parasite of *Harmolita* spp. and *Phytophaga destructor* (Say). Kelly (*1910*) gave a short account of its life history as a parasite of *P. destructor*, with brief descriptions of the egg, larva, and pupa. He observed that *allynii* parasitized the pupae of *Eridontomerus isosomatis* (Riley) and that the latter were parasites of the pupae of *allynii*.

Packard (*1916*) published a more detailed account of its biology as a parasite of *P. destructor*, with illustrations of the stalked egg, the larva, and the pupa. He noted that the eggs were deposited inside the puparium between the wall and the host larva and that about half were fastened to the wall of the puparium in a netlike structure. He found that the eggs hatched in 1½ to 5 days and that the larvae fed externally on the host within the puparium and matured in 7 to 10 days. The pupae were formed within the puparium, but in the fall only a few transformed to adults. After 9 to 24 days in the pupal stage, the emerging parasites cast the pupal skin and issued through a round hole cut through the wall of the puparium and the overlying leaf sheath. Adults were observed to fly freely, but only a few feet at a time. After locating a puparium in a grain stalk, they drilled into it and oviposited. Mated females produced progeny of both sexes. Females deposited 58 eggs on an average and lived for 48 to 56 days. The same females were observed to attack successfully both *Harmolita* spp. and *P. destructor*.

Phillips and Poos (*1921*) studied the biology of this parasite in *Harmolita* and described in detail each of the five larval instars. The egg was deposited within the cell of the *Harmolita* larva, where it was often attached to the cell wall by a fibrous net. As many as eight eggs were found in one cell, but only one adult emerged. The duration of the stages was similar to that observed by Packard. Five generations were reared in one season. The parasite overwintered as a full-grown larva in host cells in wheat stubble. Mature pupae were an intense black.

Gahan (*1933*) published a complete bibliography, an excellent review of the literature on this species, and a redescription and illustrations of the adult. He listed 29 hosts. Hill et al. (*1939*) considered it possibly the most important parasite of *P. destructor* in the Eastern States. They found that in cases of multiple parasitism, *allynii* usually dominated over other species of parasites. Chamberlain (*1941*) reared one complete and one partial generation from *Harmolita tritici* (Fitch) in Oregon.

Muesebeck et al. (*1951*) stated that the parasite is common throughout the United States and occurs in Prince Edward Island, Ontario, and Manitoba. They listed 40 hosts, which show that *allynii* is

principally a parasite of Hymenoptera, attacking phytophagous species, such as *Harmolita* spp., and numerous species of parasites. It also attacks *P. destructor* and one other cecidomyiid species. It has been reared from one species of Coleoptera and one of Orthoptera. There are also a few records of it as a parasite of leaf-mining, case-bearing, or stem-boring Lepidoptera.

E. allynii has apparently not been reared as a primary parasite of the oriental fruit moth. However, it does occur occasionally as a secondary parasite. In 1932 three specimens were reared at the Moorestown laboratory from oriental fruit moth cocoons trapped in peach orchards. One issued from a cocoon of *Glypta rufiscutellaris* taken at Olcott, N.Y., one from a cocoon of *Macrocentrus*, presumably *delicatus*, from Smithburg, Md., and the third from the cocoon of an undetermined hymenopterous parasite from Neffsville, Pa.

Genus ARACHNOPHAGA

Three species of the genus *Arachnophaga* attack the oriental fruit moth or its primary parasites. They are not abundant and very little information has been obtained on their biology as parasites of this host. Clancy (*1946a*) described the habits and immature stages of the closely related *Arachnophaga picea* (Riley) as a parasite of chrysopid cocoons. He found that the adult oviposited within the host cocoon and fed on exuding juices at stinging punctures made in the host. The larva fed externally, at first looping about and feeding at several places but later at only one. In chrysopids as many as three adults emerged from one cocoon. The life cycle from egg to adult was 23 to 44 days. The parasite pupated within the host cocoon.

KEY TO FEMALES OF ARACHNOPHAGA ATTACKING ORIENTAL FRUIT MOTH COCOONS

(Adapted from Gahan (*1943*))

1. Apex of costal cell densely ciliated distad of point where submarginal vein begins to curve toward anterior margin of wing 2
   Apex of costal cell bare except for row of slender, straight hairs on ventral surface adjacent to curve of submarginal vein ..... *frontalis* Gahan
2. Mesoscutum nearly uniformly dense punctate, dull ..... *longiceps* (Brues)
   Mesoscutum with concave posterior part and scapula less strongly sculptured than prescutum ..... *costalis* Gahan

Arachnophaga frontalis Gahan

Gahan (*1943*) recorded the rearing of *Arachnophaga frontalis* from oriental fruit moths from Moorestown, N.J., from *Thyridopteryx meadii* Hy. Edwards from Arizona, from *Anarsia lineatella* from Utah, and as a parasite of *Macrocentrus* cocoons, spider clusters, and chrysopid cocoons. When reared from oriental fruit moth cocoons containing larval parasites, *frontalis* was obtained only three times as a proved primary parasite of the oriental fruit moth and 35 times as a secondary parasite on *Macrocentrus ancylivorus* and other parasite species (Brunson and Allen *1948*).

A. frontalis was reared from gnaphosid egg sacs collected at Moorestown, N.J., on January 25, 1932. At the Moorestown laboratory *frontalis* was also reared from oriental fruit moth cocoons collected in Hartford County, Conn., and Rockingham County, Va., and from laboratory-bred cocoons exposed in peach orchards in Burlington

County, N.J. In cocoons trapped in the orchard where larva parasites and the oriental fruit moth were both present, *frontalis* was much more frequently reared as a secondary than as a primary parasite.

It was reared in moderate numbers from laboratory-bred oriental fruit moth cocoons exposed in peach orchards in Burlington County, N.J., from 1931 to 1936 and from 1956 to 1957. Either the prepupa or the pupa was successfully attacked, and in more than 50 specimens in which the host remains were examined, the number reared from each was about equal. It was reared from transforming cocoons exposed in June, July, and August and from overwintering cocoons exposed in September.

On the oriental fruit moth, *frontalis* developed as an ectoparasite. The soft tissues of parasitized prepupae or pupae were not entirely consumed. When pupae were attacked, they were broadly depressed or ruptured, usually longitudinally on the ventral aspect. Naked pupae were formed beside the body of the host. Once pupation occurred within the host pupal case. When the oriental fruit moth was the host, emerging *frontalis* left conspicuous fragments of the thick black pupal case, and it cut its way out, either through the thin silk at the end of the cocoon or the cardboard walls of its shelter. Adults that emerged from *M. ancylivorus* left the pupal fragments within the parasite cocoon, and they cut a large round hole on its side just caudad of the circular opercular area, which was not disturbed.

Males of this species are uncommon. Gahan (*1943*) found 1 among the 33 specimens included in the type series. All 41 specimens in the Moorestown collection that were reared from the oriental fruit moth or *M. ancylivorus* are females.

Arachnophaga costalis Gahan

Two of the three specimens of *Arachnophaga costalis* listed by Gahan (*1943*) were reared at the Moorestown laboratory. One of these, selected as the type, was obtained from oriental fruit moth cocoons collected in a peach orchard at Salisbury, Md., not Moorestown, N.J., as stated by Gahan. The other was reared from cocoons collected at Berlin, Md. This uncommon species was obtained only from these two places in eastern Maryland and from oriental fruit moth cocoons collected in peach orchards from 1929 to 1932. One of the two specimens reared at Moorestown was a primary parasite issuing from the pupa of the oriental fruit moth, and the other was a secondary issuing from a cocoon of *Macrocentrus ancylivorus*.

Arachnophaga longiceps (Brues)

Gahan (*1943*) stated that from a single chrysalis of *Papilio* sp. collected at Brownsville, Tex., in 1938, 30 females and 7 males of *Arachnophaga longiceps* were reared. At the Moorestown laboratory *longiceps* was reared once from the oriental fruit moth. An examination of the host remains proved that this specimen was a primary parasite. It issued from a pupa of the oriental fruit moth in one lot of laboratory-bred cocoons that were exposed in a peach orchard in June 1936.

Eupelmella vesicularis (Retzius)

Eupelmella vesicularis, a small European eupelmid, has been known to entomologists for almost two centuries. Gahan (*1933*) published an extensive bibliography of both American and European literature, redescribed the adult, and reviewed the taxonomy and biological rec-

ords. There are several synonyms, and in much of the published biological information the species is called *Eupelminus saltator* Lindm.

E. vesicularis is widely distributed in Europe and America. Gahan noted that in the United States it had not been reported from California, from States south of Virginia, or from the wheat-growing sections of Iowa, Kansas, Missouri, and Oklahoma. He observed that it is one of the most extensively polyphagous of the chalcidoids, and he listed 67 species parasitized by it in the orders Diptera, Coleoptera, Lepidoptera, Hymenoptera, and Homoptera. Muesebeck et al. (*1951*) listed 41 species as hosts, several of which are not included in Gahan's list.

The first record of the occurrence of this species in the United States was published by McConnell (*1918*), who observed that it had probably been accidentally introduced in straw. He found that it was a primary parasite of *Phytophaga destructor*, attacking both larvae and pupae, but that it was also a secondary attacking other primary parasites when they were abundant. He noted that the adult jumps actively but does not fly and that no males had been found.

Much additional biological information was obtained by Phillips and Poos (*1927*), who studied it as a parasite of *Harmolita* in Virginia, and by Muesebeck and Dohanian (*1927*), who studied it as a parasite of *Apanteles melanoscelus* in New England. Phillips and Poos observed that the egg had a pedicel and flagellum and that the egg was deposited outside the body of the host and frequently fastened to the wall of the cell by a fibrous net. Although several eggs were frequently deposited in one cell, only one larva matured. They found that the average period from egg to adult was about 24 days and that the adults lived about 26 days and deposited 10 to 11 eggs. There were six generations between May and October. These parasites hibernated as full-grown larvae in the cells. Muesebeck and Dohanian found the life history to be similar in *Apanteles*, although in this host in New England there were only three generations annually. Phillips and Poos found that in the laboratory they could readily obtain parasitism of *P. destructor* with adults reared from *Harmolita* and vice versa.

Morris (*1938*), studying *vesicularis* as a member of the parasite complex of a conifer sawfly, *Neodiprion sertifer* (Geoffroy), observed that the *vesicularis* specimen reared appeared to be a specific parasite of the primary *Dahlbominus fuscipennis* (Zetterstedt). He was unable to rear it from *Neodiprion* or any of the other parasites. He also observed that the egg was always attached by its stalk to the upper inner wall of the cocoon. This habit does not agree with that noted by other observers.

E. vesicularis was never reared at the Moorestown laboratory as a primary parasite of the oriental fruit moth. In 1932 five specimens were reared from field-collected cocoons of this host, all as secondary parasites, one from East Longmeadow, Mass., from an undetermined parasite cocoon, and four from Olcott, N.Y., three of which issued from *Glypta rufiscutellaris* cocoons.

Encyrtaspis semirufa Gahan

Encyrtaspis semirufa is distinguished from all the other chalcidoid parasites of the oriental fruit moth except *Arachnophaga* by its compressed hindtibia. It differs from *Arachnophaga* in having a broad, thin, yellowish carina on the posterior margin of the hindtibia. It is broadly rufotestaceous without metallic coloration. The lobes of

the mesoscutum are carinate posteriorly, and the reddish scutellum is conspicuously convex and has black bristles on its disc.

Gahan (*1927*) reported rearing *semirufa* as a secondary parasite of the oriental fruit moth in Georgia. Nettles (*1934*) reared it from the oriental fruit moth in South Carolina. The only other recorded hosts are an undetermined leaf skeletonizer (Gahan *1927*) and *Laetilia coccidivora* Comstock, a pyralid predator of soft scales (Gahan *1943*). Its recorded distribution is New York to Georgia and in Louisiana and Texas (Muesebeck et al. *1951*).

From 1931 to 1936 and in 1957 it was reared at the Moorestown laboratory from oriental fruit moth cocoons collected from Niagara County, N.Y., Burlington County, N.J., and Washington County, Md., and from laboratory-bred oriental fruit moth cocoons exposed in peach orchards—never more than one parasite to a lot. It was reared chiefly as a primary parasite, but once as a secondary from a *Macrocentrus* cocoon. One specimen was reared in early spring from overwintering oriental fruit moth cocoons. All specimens reared from the oriental fruit moth seemed to have been internal parasites of the pupa. They had cast the meconium and pupated within the normally inflated pupal case. The adult left conspicuous black pupal fragments in the host pupal case and gnawed off the entire cephalic end to emerge.

TORYMIDAE

Monodontomerus subobsoletus Gahan

Monodontomerus subobsoletus can be distinguished from the nearly related *Monodontomerus dentipes* (Boheman) in having the tooth of the posterior femur removed from the apex by at least twice its own length and in having the first abdominal tergite quite smooth dorsally. Gahan (*1941*) described this species from both sexes, some of which were reared from *Malacosoma americanum* from Delaware, others from *Gambrus extrematis* from New York, and from four adults reared from one laboratory-bred oriental fruit moth cocoon exposed in a peach orchard at Moorestown, N.J., in July 1935. An examination of the host remains proved that the primary host was a prepupa of the oriental fruit moth. In July 1933 two specimens were reared from an oriental fruit moth cocoon from Evesboro, N.J. From the host remains these were ascertained to be secondary parasites, probably of *Eurytoma appendigaster*.

PTEROMALIDAE

Tritneptis hemerocampae Girault

Muesebeck et al. (*1951*) stated that *Tritneptis hemerocampae* is distributed from Quebec to West Virginia and occurs also in Illinois, Colorado, and British Columbia. They listed eight Lepidoptera and one tenthredinid as hosts, including several common pests.

Some authors reported rearing it as a primary parasite, which attacks the cocoon stage. Shaffner and Griswold (*1934*) stated that it is a primary and often a secondary parasite of Macrolepidoptera in the Northeastern States and that it hibernates in host pupae. Stearns (*1928*) and Haeussler (*1930*) both reared it as a secondary parasite of the oriental fruit moth in New Jersey, the latter from the cocoons of *Macrocentrus ancylivorus*. Brunson (*1957*) reared it as a primary parasite of the oriental fruit moth from laboratory-bred cocoons exposed in a peach orchard at Marlton, N.J. The host relationship was verified from the host remains.

Dibrachys cavus (Walker)

(Fig. 26)

Dibrachys cavus, a small chalcidoid, was described long ago from Europe. It is one of the most widely distributed, abundant, and polyphagous of all the hymenopterous parasites. It occurs in Europe, North America, Asia (Li *1936*), South America (Lopez-Cristobal *1938*), and Australia (Helson *1939*). The numerous records pertaining to its distribution and hosts in North America were summarized by Muesebeck et al. (*1951*). They showed that it is generally distributed throughout the United States and Canada. The 97 hosts they listed include many species in the orders Lepidoptera, Diptera, and Hymenoptera, several species in Coleoptera, and one to several species in the families Sympherobiidae and Chrysopidae,

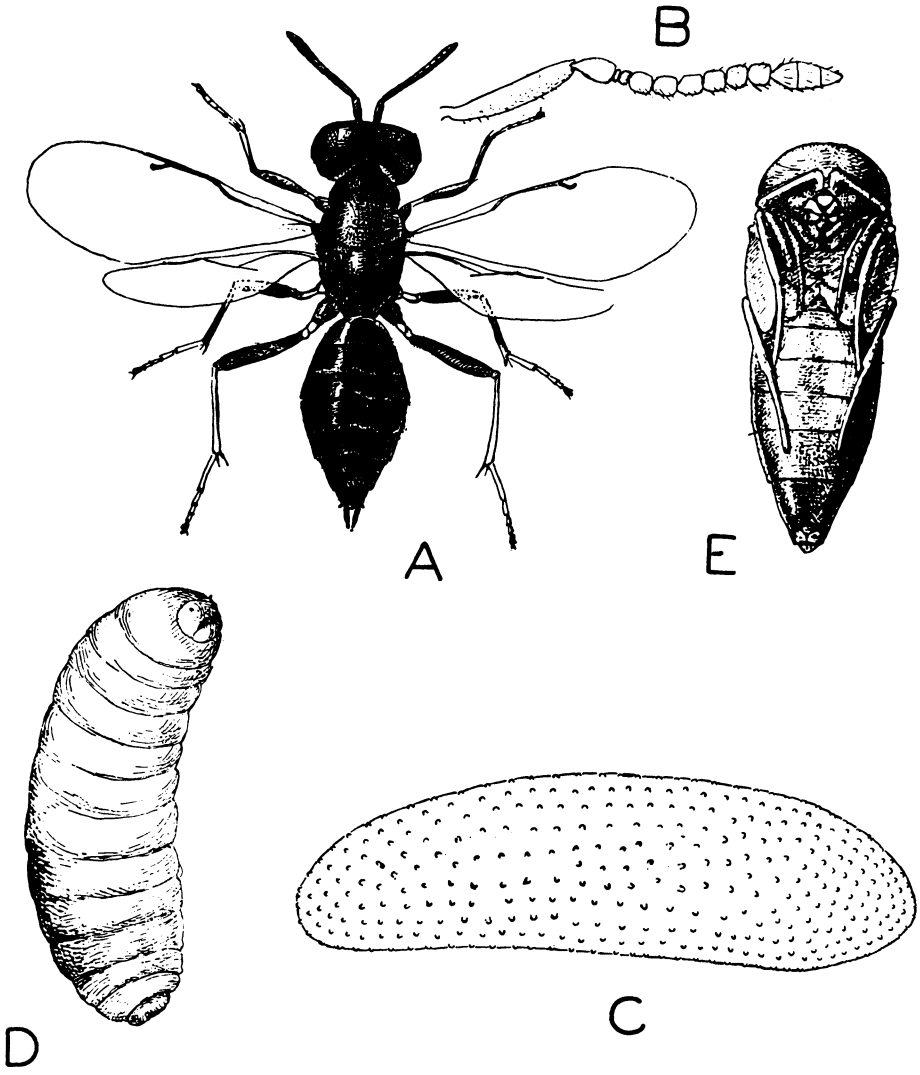

FIGURE 26.—*Dibrachys cavus: A*, Adult female; *B*, antenna; *C*, egg; *D*, larva; *E*, pupa. (*A*, *B*, *D*, and *E* from Howard (*1897*).)

and even species of spiders. They also gave an extensive synonymy. In American literature many published records refer to this species as *Dibrachys boucheanus* (Ratzeburg). The degree of divergence in the published biological information on *cavus* suggests that more than one species is involved.

Early biological observations were made by Ratzeburg (*1844*), who studied *cavus* as a secondary parasite of *Porthetria dispar* (Linnaeus) in Germany, and by Howard (*1897*), who reared it as a secondary on *Hemerocampa leucostigma* in the United States and published illustrations of the adult and immature stages (fig. 26). Snodgrass (*1917*) described the oviposition and the subsequent larval development as an internal parasite within the pupae of *H. leucostigma*. Boyce (*1941*) observed that it was an internal parasite of *Carpocapsa pomonella* pupae. However, numerous other workers reported it as an ectoparasite, usually feeding on the prepupa but occasionally on the pupa or even on the unemerged adult.

Snodgrass observed that the host pupa was paralyzed at oviposition, Marsh (*1936*) found that *Gambrus* specimens were stung directly after oviposition, but Farwick (1947) observed that *cavus* larvae did not interfere with the development of an *Apanteles* host until nearly mature, when all the body contents were rapidly consumed. All authors agreed that several to many specimens mature on one host, that they pupate within the host cocoon, that several generations occur annually, and that *cavus* hibernates as a mature larva. Muesebeck and Dohanian (*1927*) observed that *cavus* females reared from *Apanteles melanoscelus* lived for 2 to 3 months, and each produced about 250 eggs. Marsh obtained as many as 400 eggs of *cavus* reared from *Gambrus extrematis*, and he noted that the adults lived as long as 50 days. Farwick obtained similar results with females reared from *Apanteles glomeratus* (Linnaeus).

Although *cavus* is a primary parasite of many species of Lepidoptera and phytophagous Hymenoptera, it is much too frequently hyperparasitic and usually prefers the other primary parasites of these hosts. It is considered a particularly obnoxious hyperparasite of some pests because of its ability to produce several individuals per host, which permits it to increase more rapidly than any of the primary parasites of these pests. It is sometimes even a pest in mass rearing of parasites (Garman and Brigham *1933*, Garman *1934*). Despite its generally unfavorable reputation, some efforts have been made to propagate it. Doutt and Finney (*1947*) found that they could readily reproduce enormous numbers by exposing layers of mature *Gnorimoschema operculella* larvae, which were paralyzed in hot water at 155° F. for 2 minutes, and by sifting out the parasite pupae when they were fully matured.

The published records of *cavus* as a parasite of the oriental fruit moth include the following: Wood and Selkregg (*1918*), Garman (*1918*), Stearns (*1919*, *1928*), Haeussler (*1930*), Eddy and Nettles (*1931*), Allen (*1932*), Daniel (*1932*), McConnell (*1932*), Garman and Brigham (*1933*), Merritt (*1933b*), Garman (*1934*), Van Steenburgh (*1935*), Garman (*1938*), Helson (*1939*), Haeussler (*1940*), Brunson and Allen (*1948*), and Brunson (*1948*). Several of these authors did not state whether it was a primary or secondary parasite, but in all the earlier records it was listed as a secondary. Allen (*1932*) stated that it was both a primary and secondary parasite of the oriental fruit moth. Helson (*1939*) found it attacking two species of oriental fruit moth parasites in

Australia, and Haeussler (*1940*) reared it from several primary parasites of the oriental fruit moth in Japan and Korea. Brunson and Allen (*1948*) noted its preference for the primary parasites, and Brunson (*1948*) found it the most abundant secondary parasite attacking *Macrocentrus ancylivorus* in 1940.

In 1931 and 1932 *cavus* was reared at the Moorestown laboratory from oriental fruit moth cocoons collected on peach trees in Massachusetts, Connecticut, New York, New Jersey, Pennsylvania, Maryland, Virginia, and Ohio. In 1931 the examination of host remains in parasitized cocoons proved *cavus* to be both a primary and secondary parasite of the oriental fruit moth. However, the cocoons of primary parasites formed within this host's cocoons were attacked more frequently than was the oriental fruit moth. In 19 samples collected from four New Jersey counties in 1931, 88 percent of the oriental fruit moth cocoons were parasitized, but 97 percent of the cocoons parasitized by *cavus* contained primary parasites. In 19 samples collected in two Pennsylvania counties, 70 percent of the oriental fruit moth cocoons were parasitized, but 100 percent of the cocoons attacked by *cavus* contained primary parasites. In 1932 similar results were obtained from oriental fruit moth cocoons collected in several Eastern States. Whenever *M. ancylivorus* was the dominant parasite, it was heavily parasitized by *cavus*. Other primaries parasitized by *cavus* were *Macrocentrus delicatus*, *Glypta rufiscutellaris*, and *Pristomerus euryptychiae*.

When *cavus* was a primary parasite of the oriental fruit moth, it usually destroyed the prepupa, but the pupa was also frequently attacked. *D. cavus* overwintered in oriental fruit moth cocoons. In 2,485 laboratory-reared oriental fruit moth cocoons exposed on peach trees in Burlington County, N.J., the percent primary parasitization by *cavus* from 1931 to 1936 was, respectively, 2.5, 4.1, 11.1, 6.4, 9.0, and 3.3 and averaged 4.1.

In 1957 biological notes were obtained on *cavus* as a parasite of the oriental fruit moth and two of its primary parasites. It was reared throughout the spring and summer from laboratory-bred oriental fruit moth cocoons, some of which contained *M. ancylivorus*, which were exposed in peach and apple orchards.

Usually several matured on one host, and females greatly outnumbered males. In 52 cocoons containing oriental fruit moths that were parasitized when exposed in orchards, the average number of *cavus* specimens emerging per cocoon was 7 (6 females and 1 male) and the maximum 20. The average number produced in 19 *M. ancylivorus* cocoons was 5 (3 females and 2 males) and the maximum 8. From one oriental fruit moth pupa parasitized by *Pimpla inflata* in the field, nine females and one male of *cavus* were reared. *D. cavus* attacked both prepupae and pupae of the oriental fruit moth freely, but the number of prepupae parasitized was double that of the pupae attacked, and the average number reared per individual was much larger from the prepupae.

In most cocoons from which several *cavus* specimens were reared, both sexes were represented. However, 3 prepupae each produced 9 to 10 female parasites with no males, and 1 pupa produced 8 males and no females. Paralyzed oriental fruit moth prepupae were marked with numerous sclerotized sting scars, which were usually more numerous in one small area of the body. Paralysis apparently was produced at the time of oviposition by repeated stings. Usually several eggs were loosely attached to the body in

a cluster, and several other single eggs were attached at various places over the body.

The egg (fig. 26, *C*) was 0.37 by 0.12 mm., was translucent, and had a refractive sheen produced by a dense covering of nearly transparent microscopic tubercles. The larvae fed externally on oriental fruit moth pupae or prepupae within the host cocoon or externally on *M. ancylivorus* pupae or prepupae within the parasite cocoon. They completed their feeding 5 to 6 days after oviposition, leaving the shrunken but frequently only partially consumed remains of the host. The full-grown larva was 2.0 by 0.7 mm. In *M. ancylivorus* the parasites were readily recognized through the translucent walls of the parasite cocoon. On the sixth to seventh day after oviposition the larvae expelled meconia, which appeared as scattered clumps of gray or tan globular pellets. Pupation occurred 7 to 8 days after oviposition.

The pupae, which often nearly fill the cocoon cavity, were nonmobile and enclosed in a thin, nearly transparent pellicle, which became more noticeable as the pupae blackened. The period from oviposition to emergence in the oriental fruit moth and *M. ancylivorus* ranged from 14 to 21 days and averaged 18. All the parasites within one cocoon issued through one small hole. In *M. ancylivorus* cocoons they might issue at any point, and when the point selected was close to a cardboard wall, the hole was extended out through the paper. When *cavus* emerged from the oriental fruit moth host, the exit was usually through the soft silk at the end of the cocoon.

D. cavus can be distinguished from other parasites of the oriental fruit moth by means of the remains. These include scattered clumps of minute meconial pellets and several delicate, light-brown pupal skins in the cocoon of the host.

EURYTOMIDAE

Eurytoma appendigaster (Swederus)

(Fig. 27)

The genus *Eurytoma* has many species that are phytophagous and others that are parasitic on insects. *Eurytoma appendigaster* was first described more than 160 years ago. In Europe and Japan it was most frequently reported as a secondary parasite attacking braconid parasites of Lepidoptera.

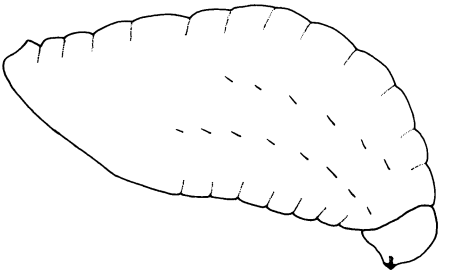

FIGURE 27.—Full-grown larva of *Eurytoma appendigaster*.

Muesebeck and Dohanian (*1927*) found that it was the most troublesome parasite of *Apanteles melanoscelus* in New England. They observed that *appendigaster* had one or two generations annually in *A. melanoscelus*. It attacked both broods and hibernated for nearly 10 months as a mature larva within the parasite cocoon. In the laboratory some adults remained alive for several months. Of five adults, three deposited no eggs and the other two 111 and 163, respectively. Several eggs were sometimes deposited in one cocoon, but only one larva matured. The eggs had a stalk and flagellum and were densely beset with blackish spines. Hatching occurred in about 2 days. The larvae had five instars. They fed extensively at puncture holes, apparently

only on the exuding juices, and became mature in 6 days. In August the pupal stage lasted 10 to 14 days and the period from egg to adult 18 to 24 days.

Proper (*1934*) found that in New England from 1929 to 1932 *appendigaster* destroyed 13.8 percent of the first generation and 69.2 percent of the second generation of *A. melanoscelus* cocoons from *Porthetria dispar*, and a much smaller percentage of *Apanteles lacteicolor* Viereck from *Nygmia phaeorrhoea* and of *A. solitarius* (Ratzeburg) from *Stilpnotia salicis* (Linnaeus). Rosenberg (*1934*) recorded it as a primary parasite of *Carpocapsa pomonella* in France and a secondary attacking several of its primary parasites. He published illustrations of the egg, the head of the first-instar larva, and the mature larva.

Muesebeck et al. (*1951*) recorded *appendigaster* as occurring in Ontario, New England, New Jersey, Pennsylvania, and Wisconsin. Only the northern part of the area infested by the oriental fruit moth lies within this area. They recorded 13 North American hosts, showing that *appendigaster* is primarily a parasite of casebearers, fruitworms, and stem borers in the Lepidoptera, or of the braconid and ichneumonid parasites of large Lepidoptera that form their cocoons away from the host remains.

Since *appendigaster* is the only common species of *Eurytoma* attacking the oriental fruit moth, it is probably identical with the *Eurytoma* sp. mentioned by Garman (*1918*) as a parasite of *Macrocentrus* reared from oriental fruit moths in Maryland and also mentioned by Driggers (*1929*) as the common secondary parasite attacking *Glypta rufiscutellaris* cocoons in overwintered oriental fruit moth cocoons collected in New Jersey.

Haeussler (*1933*) found that *appendigaster* was a common parasite of oriental fruit moth cocoons collected from or exposed in peach orchards in southern France and Italy in 1931, and also he (*1940*) found it in Japan and Korea in 1932 and 1933. He noted that parasitization in the cocoons of this host ranged up to 8.9 percent in Japan and 25.0 percent in Korea, but that *appendigaster* was a secondary parasite in 57.8 percent of the cocoons attacked. He found that as a primary it developed on the prepupa or pupa within the cocoon and that it hibernated as a mature larva in the oriental fruit moth cocoon. Usually one parasite issued from a cocoon. He observed that 79.9 percent of 1,350 adults reared were females. Brunson (*1948*) found that it was a common parasite in New Jersey of *Macrocentrus ancylivorus* in cocoons of the oriental fruit moth.

At the Moorestown laboratory in 1931 and 1932 *appendigaster* was reared from oriental fruit moth cocoons collected from peach orchards in the following counties: Hampden, Mass., Hartford, Conn., Niagara and Rockland, N.Y., Burlington, Mercer, and Monmouth, N.J., and Erie and Lorain, Ohio. In these cocoons it occurred much more frequently as a secondary parasite than as a primary. In 18 cocoons it was a parasite of *G. rufiscutellaris*, in 16 of *M. ancylivorus*, in 1 probably of *Macrocentrus instabilis*, in 7 of undetermined parasites, and in 3, or only 7 percent of the total, it was a primary parasite of the oriental fruit moth.

However, it was also reared in considerable numbers from 1931 to 1936 as a primary parasite of the oriental fruit moth in parasite-free cocoons exposed in orchards in Burlington County, N.J. Parasitism occurred continuously from mid-May to late September. From the 39 lots in which *appendigaster* was reared, 9.2 percent of the 2,241

oriental fruit moth cocoons were parasitized by it. This parasite would probably be a fairly effective primary in sections where the usual larval parasites are lacking. In the Moorestown collection 83 percent of the 119 *appendigaster* specimens that emerged from cocoons parasitized in the field were females. This parasite attacked both prepupae and pupae freely.

In 1957 an attempt was made at the Moorestown laboratory to breed *appendigaster* on oriental fruit moth cocoons. No parasitism was obtained on the oriental fruit moth pupae and prepupae exposed, but a few larvae were reared on *M. ancylivorus* in oriental fruit moth cocoons. The parasite larvae developed as ectoparasites on the prepupae of *M. ancylivorus*, and they completed their feeding in 10 to 11 days after oviposition. Four larvae matured in this host between July 10 and 31. After casting the meconium, they ceased developing. They hibernated as mature larvae. This was the only cocoon parasite reared at Moorestown that had fewer generations than the host. The full-grown larva (fig. 27) was 3.5 mm. long and had minute antennae on its light-brown head. On the body there were two lateral rows of fine brown hairs. Beneath the cuticle there was a closely packed layer of glistening, beadlike fat bodies.

The remains of this parasite in oriental fruit moth cocoons serve to identify it. When oriental fruit moths were the primary host, the prepupa or pupa was not completely consumed. The meconium and a flexible, translucent, brown pupal exuvium lay beside them or occasionally in an excavated pupal case. A black eggshell, which was 0.5 mm. long, easily visible under low-power magnification, and closely beset with long black spines, could usually be found on the host body or in the cocoon. Emergence was through the soft silk at the end of the cocoon.

Eurytoma Sp.

Two *Eurytoma* sp. females in the Moorestown collection (Oriental Fruit Moth Investigations Nos. 2004 and 2006) were definitely reared from oriental fruit moth cocoons. One was reared from a prepupa and the other from a pupa in parasite-free cocoons exposed in peach orchards at Moorestown and Parry, N.J., in 1934. They were determined by A. B. Gahan at the U.S. National Museum. They were much smaller than *Eurytoma appendigaster*.

CHALCIDIDAE

Five North American species of Chalcididae are known to attack the oriental fruit moth. Although they have been reared occasionally as secondary parasites on other lepidopterous hosts, they have been found only as primaries in the oriental fruit moth. They are readily recognized by the reduced chalcidoid wing venation and the conspicuously enlarged hindfemur.

KEY TO SPECIES OF CHALCIDIDAE ATTACKING ORIENTAL FRUIT MOTH COCOONS

1. Abdomen nearly sessile 2
   Abdomen petiolate ..... *Spilochalcis side* (Wlk.)
2. Segments of flagellum distinctly longer than wide 4
   Segments of flagellum shorter than wide 3
3. Postgenal carina absent ..... *Brachymeria ovata ovata* (Say)
   Postgenal carina present ..... *Brachymeria hammari* (Cwfd.)
4. Antennal scape black; front, middle, and hind femora black ..... *Haltichella xanticles* (Wlk.)
   Antennal scape usually red; front and middle femora and basal half of hindfemur red ..... *Haltichella longicornis* Ashm.

Haltichella xanticles (Walker)

(Fig. 28)

Haltichella xanticles according to Muesebeck et al. (*1951*) is distributed from Quebec to Florida and in Illinois, Ohio, Kansas, and Nebraska. These authors recorded the three lepidopterous hosts—*Rhyacionia buoliana* (Schiffermüller), *Bucculatrix canadensisella* Chambers, and a lichen-feeding psychid *Solenobia walshella* Clemens—and the imported braconid *Apanteles melanoscelus*. Friend (*1927*) found that it was a pupal parasite of *B. canadensisella*, in which it overwintered. Muesebeck and Dohanian (*1927*) reared it occasionally as a parasite of *A. melanoscelus*, in which there were two to three generations annually. The cycle from egg to adult was 30 to 40 days. It hibernated as a mature larva, and the adults appeared in mid-June.

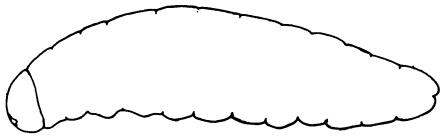

FIGURE 28.—Immature larva of *Haltichella xanticles*.

At the Moorestown laboratory this parasite was reared in 1932 as a primary parasite of oriental fruit moth pupae from cocoons collected in peach orchards in Botetourt and Roanoke Counties, Va. It was also reared several times from laboratory-bred cocoons exposed in peach orchards in Burlington County, N.J. No secondary parasitism of the oriental fruit moth by *xanticles* was observed. Specimens reared from the oriental fruit moth were about equally divided between the two sexes.

In June 1957, 14 *xanticles* specimens were reared from one lot of laboratory-bred oriental fruit moth cocoons, which was exposed in an abandoned peach orchard at Hainesport, N.J. Several of these specimens were placed in a glass-tube breeding cage with freshly formed oriental fruit moth pupae. Only a few of these pupae were parasitized. The parasites oviposited through the cardboard walls of the cocoon shelter. One host pupa had five small puncture wounds, chiefly in the ventral thoracic area. The pupae were paralyzed when the larvae were half grown and may have been immobilized much earlier.

The developing larvae (fig. 28) were encapsulated in a viscous mass of host tissue. Feeding was completed 8 to 10 days after oviposition. The mature larva was a robust, sluggish, brownish-yellow grub, which nearly filled the pupal case, although some unconsumed fresh tissue remained after feeding had been completed. *H. xanticles* pupated within the host pupal case. The pupa was enclosed in a thin, nearly transparent, flexible pellicle. The adults emerged by cutting round holes through the pupal cases at nearly any point. Some cut their way out through the silken wall at the end of the host cocoon; others gnawed through the cardboard walls of the cocoon shelter.

The remains of *xanticles* in the host cocoon were indistinguishable from those of *Haltichella longicornis* Ashmead and the two species of *Brachymeria* parasitic on the oriental fruit moth, but they serve to separate *xanticles* from several other species that emerge from the oriental fruit moth pupae. There was no cocoon. A delicate, light-brown pupal exuvium lay in the host pupa on top of the meconium. The round exit hole was not always at the anterior end of the pupal case. The pupal walls of the host were thick and blotchy from patches of desiccated host tissue.

Haltichella longicornis Ashmead

The oriental fruit moth is the only species from which *Haltichella longicornis* has been reared. Eddy and Nettles (*1931*) and Nettles (*1934*) reared this parasite from host pupae collected on harvested peaches and under trap bands in peach orchards in South Carolina in 1931 and 1932. Nettles found it the most common pupal parasite of the oriental fruit moth in 1932. He propagated it on the oriental fruit moth and found the development period was 15 to 18 days and that the adults lived on an average for about 10 days.

Genus BRACHYMERIA

Dowden (*1935*) published an excellent review of the biological literature of the genus *Brachymeria*. There are more than 150 described species, most of which are found in tropical or subtropical climates. Many are primary parasites of Lepidoptera, but some attack sarcophagid puparia, and a few are hyperparasitic attacking tachinid parasites of Lepidoptera. The biology of three species has been studied in detail—*Brachymeria fonscolombei* (Dufour) by Roberts (*1933*) and *B. intermedia* (Nees) and *B. compsilurae* (Crawford) by Dowden (*1935*). There is considerable diversity in the habits and life histories of these species.

Brachymeria ovata ovata (Say) and *B. hammari* (Crawford) are parasites of the oriental fruit moth. In *B. ovata ovata* the postgenal carina is absent; in *B. hammari* it is present. Neither of these species was ever reared at the Moorestown laboratory.

Brachymeria hammari (Crawford)

Brachymeria hammari was originally described in 1915 from specimens reared in New Mexico from *Archips argyrospilus* (Walker). Muesebeck et al. (*1951*), in addition to this host, listed it as parasitic on the oriental fruit moth, *Ancylis comptana fragariae*, and *Filatima monotaeniella* (Bottimer). They recorded that it was distributed in South Carolina, Missouri, Texas, and New Mexico. Nickels et al. (*1950*) found it occasionally as a solitary internal parasite of *Acrobasis caryae*, pupating within the host pupa. They stated that it also attacked *Acrobasis juglandis* and *Laspeyresia caryana*. As a parasite of the oriental fruit moth it was first reported by Eddy and Nettles (*1931*), with further notes by Nettles (*1934*). They found that it was the second most abundant pupal parasite of the oriental fruit moth in South Carolina and that the parasite had a development period of 15 to 18 days and the adult an average longevity of 8 days.

Brachymeria ovata ovata (Say)

Brachymeria ovata ovata was reported by Muesebeck et al. (*1951*) as occurring from Quebec to Florida and Texas and in Nebraska, New Mexico, California, and Oregon. It was also reported from Mexico, Guatemala, and Panama (Dalla Torre *1898*) and Cuba (Bruner *1935*). The recorded hosts summarized by Muesebeck et al. include 35 species of Lepidoptera, which have a wide range of size and habit, and one tachinid species. Howard (*1897*) observed that it was an internal parasite of the pupa. It pupated within the host remains and emerged through a round hole cut through the pupal case, leaving within it an easily recognized pupal exuvium. Even from a large host such as *Hemerocampa*, only one parasite issued from each individual. He also noted that *ovata ovata* may

attack moth pupae that are naked or through the walls of the cocoons, and it may attack tachinid parasites through the integument of a dead caterpillar. The record of emergence from *Hemerocampa* indicated that this parasite probably hibernated as an adult. Walley (*1953*) reported that it attacks mature larvae as well as pupae.

As a parasite of the oriental fruit moth, *ovata ovata* was reared only in South Carolina. Nettles (*1934*) found it to be the third most common pupal parasite of this host.

Spilochalcis side (Walker)

Scattered information on the biology of *Spilochalcis side* appears under several names, some of which are synonyms and others misidentifications (Burks *1940*). Muesebeck et al. (*1951*) listed it as a primary parasite of 18 Lepidoptera, 3 Coleoptera, and 8 parasitic Hymenoptera. Several workers who studied it in detail found it occurring more frequently as a secondary than as a primary parasite. Marsh (*1917*) observed it only as a secondary parasite of *Plutella maculipennis* (Curtis), parasitizing *Horogenes plutellae* (Viereck). Cushman (*1927*) considered it almost certainly a secondary parasite of *Rhyacionia frustrana*. Vickery (*1929*) found it only as a secondary parasite of *Laphygma frugiperda* (J. E. Smith), parasitizing *Meteorus laphygmae* Viereck. Other authors submitted convincing evidence that *side* also attacked phytophagous insects as a primary parasite.

Doner (*1936*) stated that eggs were deposited within the pupae of *Coleophora pruniella* Clemens, one to each pupa, from which endoparasitic larvae hatched. When development was completed, pupation occurred within the shriveled pupa of the host. Clancy (*1946b*) found it parasitizing the cocoons of *Bucculatrix thurberiella* Busck, and Carlson et al. (*1951*) observed it attacking larvae of *Ceutorhynchus assimilis* (Paykull). It is widely distributed in Canada and throughout the United States.

Nettles (*1934*) reared *side* (misidentified as *Spilochalcis delira* (Cresson)) as a primary parasite from five oriental fruit moth pupae collected in 1932 in peach orchards in South Carolina.

Bethylidae

The Bethylidae family includes species of small black wasps, which run with antlike agility. Those in several genera are gregarious primary parasites in the cocoons of small Lepidoptera.

Goniozus foveolatus Ashmead

Goniozus foveolatus is the only known North American bethylid species that is parasitic on the oriental fruit moth. Probably this was the species reported from Leesburg, Va., in 1919 (Stearns *1919*), although specimens cannot now be located for reexamination. In 1931 Eddy and Nettles (*1931*) reported rearing *Goniozus columbianus* Ashmead from the oriental fruit moth in South Carolina. It is quite probable that this was *foveolatus* incorrectly identified, since one specimen, perhaps of the same series, reared at Clemson, S.C., by W. C. Nettles on August 27, 1930, was recently identified by K. V. Krombein and C. F. W. Muesebeck at the U.S. National Museum as *foveolatus*. The six specimens reared by Neiswander from Avon

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Lake, Ohio, on September 5 and 7, 1933, and reported (Neiswander *1936*) as *G. columbianus* have recently been identified by Krombein and Muesebeck as *foveolatus*.

Eddy and Nettles found that this parasite developed gregariously (four to one host larva) on the cocooned larva of the oriental fruit moth.

ALTERNATE HOSTS

The study of the North American hosts of the oriental fruit moth is of interest because it provides considerable information on how a relatively static biotic complex has been changed within a few years by the introduction of a new factor—the fruit- and twig-feeding olethreutid, the oriental fruit moth. The response of the biotic environment to several species of introduced pests, such as *Porthetria dispar*, has been negligible, but this is not true of the oriental fruit moth. Over 90 species of North American Hymenoptera and Diptera have accepted the oriental fruit moth as a host, and some are as yet not recorded from any other host.

The known alternate hosts of the oriental fruit moth parasites in the United States have been listed (p. 113). Sixteen parasite species that are extensively polyphagous and therefore not closely bound ecologically to any one of their many hosts have been excluded from this list. One of these is the widely distributed *Nemorilla floralis* and one is the cosmopolitan *Trichogramma minutum*, which parasitizes the thin-shelled eggs of insects in many orders. Another is *Perilampus fulvicornis fulvicornis*, which has a highly specialized method of attacking primary parasite larvae. Two others are braconids—*Bracon mellitor* and *B. gelechiae*. The remaining 11 are ichneumonids or chalcidoids—*Scambus pterophori*, *S. hispae*, *Itoplectis conquisitor*, *Gelis tenellus*, *Eupelmus allynii*, *E. cyaniceps cyaniceps*, *E. cyaniceps amicus*, *Eupelmella vesicularis*, *Dibrachys cavus*, *Brachymeria ovata ovata*, and *Spilochalcis side*. Although most of the parasites of the oriental fruit moth are internal parasites, the 2 braconids mentioned and all but 3 of the 11 ichneumonids and chalcidoids are ectoparasites. Their larvae hatch from eggs placed on or near the host, and they feed by tearing holes through the integument. This habit is much less specialized than when the parasites oviposit within the body of the host.

The following species are rarely parasitic on the oriental fruit moth, and since parasitism on that host is probably not yet an established habit, they are omitted from the list: *Dichaetoneura leucoptera*, *Agathis rubripes*, *Apanteles polychrosidis*, *Microgaster epagoges*, *Bracon politiventris*, *Toxophoroides albomarginatus albomarginatus*, *Campoplex tortricidis*, *Horogenes rosanae*, *Temelucha cookii*, *Bathythrix peregrina*, *Mastrus carpocapsae*, *Phobetes thyridopteryx*, *Gelis apantelis*, *Gelis nocuus*, and *Arachnophaga longiceps*.

All but 10 of the 194 alternate hosts listed are Lepidoptera either in the primary or secondary sense. However, species of *Arachnophaga*, *Lymeon*, and *Lixophaga* have hosts in three families of Coleoptera and in one family each of Neuroptera and Arachnida. The genera *Tritneptis*, *Lixophaga*, and *Syntomosphyrum* have several hosts among the Macrolepidoptera, especially in the families Phalaenidae, Arctiidae, and Lymantriidae, but they have relatively few hosts among the Microlepidoptera. Many of the chalcid parasites of the oriental fruit moth and a few ichneumonids

also have alternate hosts among the primary parasites of Lepidoptera. However, 84 percent of all the host-parasite records of the species listed involve Microlepidoptera. There are more records of the olethreutids than any other family, but tortricids and gelechiids are also well represented. In this list *Carpocapsa pomonella* is the alternate host of 23 oriental fruit moth parasites, *Epiblema strenuana* of 11, *Laspeyresia caryana* of 10, and *Ancylis comptana fragariae* of 9. All four are close relatives in the family Olethreutidae, three have similar larval habits, and three are abundant in the same environment as the oriental fruit moth.

It is evident that there is wide diversity in the relationships and life histories of the alternate hosts of the oriental fruit moth, but most of the North American parasites that have accepted this host are species that attack small Lepidoptera whose larvae are protected, such as fruit, nut, or stem borers, casebearers, or leaf rollers.

ALTERNATE HOSTS OF ORIENTAL FRUIT MOTH PARASITES

Host	*Parasite*
NEUROPTERA	
Chrysopidae	*Arachnophaga frontalis*
COLEOPTERA	
Bostrichidae	
Amphicerus bicaudatus (Say), apple twig borer.	*Lixophaga variabilis*
Cerambycidae	
Oberea bimaculata (Oliv.), raspberry cane borer.	*Lixophaga variabilis*
Curculionidae	
Lixus scrobicolis Boh.	*Lixophaga variabilis*
LEPIDOPTERA	
Psychidae	
Eurukuttarus confederatus Grote	*Pimpla aequalis, Gambrus ultimus, Lymeon orbum*
Solenobia walshella Clem.	*Haltichella xanticles*
Thyridopteryx ephemeraeformis (Haw.), bagworm.	*Anachaetopsis tortricis*
Thyridopteryx meadi Hy. Edw.	*Arachnophaga frontalis*
Tineidae	
Nemapogon granella (L.), European grain moth.	*Goniozus foveolatus*
Lyonetiidae	
Bucculatrix canadensisella Chamb., birch skeletonizer.	*Haltichella xanticles*
Gracilariidae	
Gracilaria elongella (L.)	*Microgaster ecdytolophae*
Gracilaria negundella Chamb.	*Goniozus foveolatus*
Coleophoridae	
Coleophora alnicella Heinr.	*Agathis cincta*
Coleophora asterophagella (McD.)	*Microgaster ecdytolophae*
Coleophora atlantica Heinr.	*Agathis cincta*
Coleophora cinerella Chamb.	*Agathis cincta*
Coleophora laricella (Hbn.), larch casebearer.	*Agathis cincta*
Coleophora limosipennella (Dup.), elm casebearer.	*Agathis cincta*
Coleophora malivorella Riley, pistol casebearer.	*Anachaetopsis tortricis, Macrocentrus instabilis, Tritneptis hemerocampae, Goniozus foveolatus*
Coleophora occidentis Zell., cigar casebearer.	*Horogenes obliteratus*
Coleophora pruniella Clem., cherry casebearer.	*Eurytoma appendigaster*

Host	Parasite
LEPIDOPTERA—Continued	
Coleophoridae—Continued	
Coleophora salicivorella McD.	*Agathis cincta*
Coleophora salmani Heinr., birch casebearer.	*Agathis cincta, Temelucha forbesi, Pimpla aequalis*
Coleophora tiliaefoliella Clem.	*Agathis cincta*
Coleophora spp.	*Gambrus ultimus, Lymeon orbum*
Yponomeutidae	
Argyresthia oreasella Clem.	*Horogenes obliteratus*
Argyresthia thuiella (Pack.)	*Apanteles epinotiae*
Xyrosaris celastrusella (Kearf.)	*Horogenes obliteratus*
Aegeriidae	
Sanninoidea exitiosa (Say), peach tree borer.	*Cryptus albitarsis albitarsis*
Synanthedon pictipes (G. & R.), lesser peach tree borer.	*Pimpla inflata*
Thamnosphecia pyri (Harris)	*Pimpla aequalis*
Stenomidae	
Stenoma algidella (Wlk.)	*Syntomosphyrum esurus*
Glyphipterygidae	
Anthophila pariana (Clerck)	*Horogenes obliteratus*
Oecophoridae	
Psilocorsis sp.	*Atrometus clavipes*
Gelechiidae	
Anacampsis fragariella Busck	*Agathis cincta*
Anacampsis innocuella (Zell.)	*Agathis annulipes*
Anacampsis sp.	*Macrocentrus ancylivorus*
Anarsia lineatella Zell., peach twig borer.	*Anachaetopsis tortricis, Arachnophaga frontalis*
Aristotelia absconditella (Wlk.)	*Macrocentrus delicatus*
? *Aristotelia rubidella* (Clem.)	*Horogenes obliteratus*
Aroga trialbamaculella (Chamb.)	*Temelucha forbesi*
Arogalea cristifasciella (Chamb.)	*Microgaster ecdytolophae*
Chrysopora hermannella (F.)	*Agathis cincta*
Dichomeris lingulella Hbn., palmerworm.	*Agathis cincta, Apanteles epinotiae, Horogenes obliteratus*
Dichomeris marginella (F.)	*Pimpla aequalis*
Filatima monotaeniella (Bott.)	*Brachymeria hammari*
Filatima persicaeella (Murtf.)	*Temelucha forbesi*
Gelechia spp.	*Ascogaster quadridentata*
Gnorimoschema axenopsis (Meyr.)	*Temelucha minor*
Gnorimoschema chenopodiella Busck	*Agathis cincta*
Gnorimoschema gallaesolidaginis (Riley)	*Apanteles cacoeciae, Pristomerus euryptychiae*
Gnorimoschema operculella (Zell.), potato tuberworm.	*Macrocentrus ancylivorus*
Isophrictis rudbeckiella Bott.	*Temelucha minor*
Keiferia lycopersicella (Busck), tomato pinworm.	*Apanteles epinotiae*
Pectinophora gossypiella (Saund.), pink bollworm.	*Anachaetopsis tortricis*
Recurvaria piceaella Kearf.	*Microgaster ecdytolophae*
Trichotaphe levisella Fyles	*Mastrus smithii*
Momphidae	
Blastodacna curvilineella Chamb.	*Eurytoma appendigaster*
Blastodacna sp.	*Temelucha epagoges*
Mompha eliosella (Clem.)	*Temelucha epagoges*
Walshia amorphella Clem.	*Phaeogenes walshiae walshiae, Microgaster ecdytolophae, Pristomerus euryptychiae*
Cosmopterygidae	
Homaledra sabalella (Chamb.), palm leaf skeletonizer.	*Macrocentrus instabilis, Lymeon orbum, Eupelmus limneriae*
Tortricidae	
Acleris logiana (L.)	*Meteorus trachynotus*
Acleris minuta (Rob.)	*Horogenes obliteratus*

Host	Parasite
LEPIDOPTERA—Continued	
Tortricidae—Continued	
Acleris oxycoccana (Pack.)	*Macrocentrus ancylivorus*
Acleris variana (Fern.)	*Atrometus clavipes, Horogenes obliteratus*
Acleris sp.=(*Peronea* sp.)	*Agathis cincta*
Archips argyrospilus (Wlk.), fruit-tree leaf roller.	*Meteorus trachynotus, Apanteles cacoeciae, A. clavatus, Brachymeria hammari*
Archips cerasivoranus (Fitch), ugly-nest caterpillar.	*Temelucha epagoges, Labrorychus prismaticus*
Archips semiferanus (Wlk.)	*Apanteles cacoeciae*
Argyrotaenia citrana (Fern.), orange tortrix.	*Meteorus trachynotus*
Argyrotaenia velutinana (Wlk.), red-banded leaf roller.	*Agathis cincta, Temelucha forbesi, Horogenes obliteratus*
Argyrotaza semipurpurana (Kearf.)	*Glypta rufiscutellaris*
Choristoneura conflictana (Wlk.), large aspen tortrix.	*Agathis annulipes, A. cincta*
Choristoneura fumiferana (Clem.), spruce budworm.	*Meteorus trachynotus*
Cnephasia longana (Haw.), omnivorous leaf tier.	*Agathis cincta*
Coelostathma discopunctana Clem.	*Agathis annulipes*
Epinotia sp.	*Apanteles cacoeciae*
Platynota flavedana Clem.	*Anachaetopsis tortricis*
Spargonothis sulfurana (F.)	*Anachaetopsis tortricis, Meteorus trachynotus, Temelucha epagoges*
Tortrix sp.	*Apanteles cacoeciae*
Phaloniidae	
Phalonia hospes (Wlshm.), banded sunflower moth.	*Macrocentrus ancylivorus*
Phalonia oenotherana Riley	*Lixophaga plumbea, Temelucha epagoges*
Phalonia sp.	*Apanteles epinotiae*
Olethreutidae	
Anchylopera nebeculana Clem.	*Goniozus foveolatus*
Ancylis comptana (Froel.)	*Temelucha cookii, Pristomerus euryptychiae, Phaeogenes walshiae walshiae*
Ancylis comptana fragariae (W. & R.), strawberry leaf roller.	*Anachaetopsis tortricis, Meteorus trachynotus, Macrocentrus ancylivorus, Eubadizon pleurale, Agathis annulipes, Temelucha cookii, Gambrus ultimus, Brachymeria hammari, Goniozus foveolatus*
Ancylis sp.	*Meteorus trachynotus*
Carpocapsa pomonella (L.), codling moth.	*Lixophaga variabilis, Anachaetopsis tortricis, Macrocentrus ancylivorus, M. delicatus, M. instabilis, Eubadizon pleurale, Microgaster ecdytolophae, Ascogaster quadridentata, Phanerotoma fasciata, Glypta rufiscutellaris, Temelucha minor, T. epagoges, T. carpocapsae, Pristomerus euryptychiae, P. austrinus, Perilampus fulvicornis prothoracicus, Calliephialtes grapholithae, Apistephialtes variatipes, Pimpla aequalis, P. inflata, Cryptus albitarsis albitarsis, Mastrus pilifrons, Tritneptis hemerocampae, Eurytoma appendigaster*
Ecdytolopha insiticiana Zell., locust twig borer.	*Phanerotoma fasciata, Pristomerus euryptychiae*
Epiblema obfuscana (Dyar)	*Glypta rufiscutellaris*

Host	Parasite
LEPIDOPTERA—Continued	
Olethreutidae—Continued	
Epiblema otiosana (Clem.), bidens borer	*Lixophaga variabilis, Macrocentrus pallisteri, Pristomerus euryptychiae*
Epiblema scudderiana (Clem.)	*Apanteles cacoeciae, Macrocentrus pallisteri, Glypta rufiscutellaris, Pristomerus austrinus*
Epiblema strenuana (Wlk.), ragweed borer.	*Lixophaga variabilis, Macrocentrus ancylivorus, M. delicatus, M. pallisteri, Glypta rufiscutellaris, Temelucha minor, T. forbesi, T. epagoges, Pristomerus euryptychiae, Calliephialtes grapholithae, Phaeogenes walshiae walshiae*
Epiblema tripartitana (Zell.)	*Macrocentrus delicatus*
Epinotia laracana (Kearf.)	*Glypta rufiscutellaris*
Epinotia subviridis Heinr.	*Apanteles clavatus*
Epinotia sp.	*Apanteles cacoeciae*
Eumarozia malachitana (Zell.)	*Agathis annulipes*
Exartema sericoranum (Wlshm.)	*Macrocentrus ancylivorus*
Grapholitha interstinctana (Clem.), clover head caterpillar.	*Agathis annulipes, Phanerotoma fasciata*
Grapholitha packardi Zell., cherry fruitworm.	*Phanerotoma fasciata, Glypta rufiscutellaris*
Grapholitha prunivora (Walsh), lesser appleworm.	*Agathis festiva, Ascogaster quadridentata, Glypta rufiscutellaris*
Grapholitha tristrigana (Clem.)	*Macrocentrus delicatus*
Gretchena bolliana (Sling.), pecan bud moth.	*Macrocentrus delicatus, Pimpla inflata, Pristomerus austrinus*
Gypsonoma salicicolana (Clem.)	*Apanteles epinotiae*
Laspeyresia caryana (Fitch), hickory shuckworm.	*Lixophaga variabilis, Macrocentrus instabilis, Agathis annulipes, Apanteles epinotiae, Microgaster ecdytolophae, Phanerotoma fasciata, Glypta rufiscutellaris, Calliephialtes grapholithae, Brachymeria hammari, Goniozus foveolatus*
Laspeyresia nigricana (Steph.), pea moth.	*Ascogaster quadridentata, Phanerotoma fasciata*
Lobesia carduana (Busck)	*Pristomerus euryptychiae*
Melissopus latiferreanus (Wlshm.), filbertworm.	*Anachaetopsis tortricis, Macrocentrus ancylivorus, Phanerotoma fasciata, Glypta rufiscutellaris*
Paralobesia viteana (Clem.), grape berry moth.	*Macrocentrus ancylivorus, Ascogaster quadridentata, Horogenes obliteratus, Gambrus ultimus, Goniozus foveolatus*
Proteoteras aesculana Riley	*Glypta rufiscutellaris, Horogenes obliteratus*
Proteoteras willingana (Kearf.)	*Pristomerus euryptychiae*
Rhopobota naevana (Hbn.), blackheaded fireworm.	*Macrocentrus delicatus, Temelucha minor, T. forbesi*
Rhyacionia buoliana (Schiff.), European pine shoot moth.	*Eurytoma appendigaster, Haltichella xanticles*
Rhyacionia frustrana (Comst.), Nantucket pine moth.	*Lixophaga mediocris, L. plumbea, Temelucha epagoges*
Rhyacionia frustrana bushnelli (Busck)	*Temelucha epagoges*
Rhyacionia rigidana (Fern.)	*Macrocentrus instabilis*
Sciaphila duplex (Wlshm.)	*Agathis annulipes, Apanteles cacoeciae*
Strepsicrates smithiana (Wlshm.)	*Agathis annulipes*
Suleima helianthana (Riley)	*Lixophaga variabilis, L. mediocris, Apanteles epinotiae, Temelucha epagoges, Pristomerus euryptychiae*

Host	Parasite
LEPIDOPTERA—Continued	
Phycitidae	
Acrobasis betulella Hulst, birch tube maker.	*Macrocentrus instabilis*
Acrobasis caryae Grote, pecan nut casebearer.	*Macrocentrus instabilis, Apanteles cacoeciae, A. epinotiae, Pristomerus euryptychiae, Calliephialtes grapholithae, Brachymeria hammari, Goniozus foveolatus*
Acrobasis caryivorella Rag.	*Macrocentrus instabilis, Apanteles epinotiae, Pristomerus euryptychiae, P. austrinus, Goniozus foveolatus*
Acrobasis hebescella Hulst	*Macrocentrus instabilis*
Acrobasis juglandis (LeB.), pecan leaf casebearer.	*Macrocentrus instabilis, Pristomerus euryptychiae, Calliephialtes grapholithae, Brachymeria hammari*
Acrobasis rubrifasciella Pack.	*Macrocentrus instabilis*
Acrobasis vaccinii Riley, cranberry fruitworm.	*Pristomerus austrinus*
Acrobasis spp.	*Agathis annulipes, Calliephialtes grapholithae*
Canarsia sp.	*Macrocentrus ancylivorus*
Euzophera ostricolorella Hulst	*Macrocentrus delicatus*
Homoeosoma electellum (Hulst), sunflower moth.	*Anachaetopsis tortricis, Macrocentrus ancylivorus, Temelucha epagoges*
Laetilia coccidivora Comst.	*Encyrtaspis semirufa*
Mineola sp.	*Pimpla aequalis*
Psorosina hammondi (Riley)	*Microgaster ecdytolophae, Cryptus albitarsis albitarsis*
Salebriaria tenebrosella (Hulst)	*Pimpla inflata*
"*Salebria* sp."	*Agathis cincta*
Epipaschiidae	
Tetralopha scortealis (Led.), lespedeza webworm.	*Macrocentrus delicatus*
Tetralopha subcanalis (Wlk.)	*Macrocentrus delicatus*
Crambidae	
Diatraea saccharalis (F.), sugarcane borer.	*Syntomosphyrum esurus*
Thyrididae	
Meskea dyspteraria Grote	*Calliephialtes grapholithae*
Pyraustidae	
Desmia funeralis (Hbn.), grape leaf folder.	*Lixophaga variabilis, Anachaetopsis tortricis, Ascogaster quadridentata, Horogenes obliteratus*
Lineodes vulnifica Dyar	*Lymeon orbum*
Pachyzancla bipunctalis (F.), southern beet webworm.	*Gambrus ultimus*
Phlyctaenia coronata tertialis (Guen.)	*Gambrus ultimus*
Pyrausta ainsliei Heinr., smartweed borer.	*Microgaster ecdytolophae*
Pyrausta nubilalis (Hbn.), European corn borer.	*Lixophaga variabilis, Macrocentrus delicatus, Labrorychus prismaticus, Temelucha minor, Gambrus ultimus*
Pyrausta penitalis (Grote)	*Lixophaga variabilis, Labrorychus prismaticus*
Pterophoridae	
Pterophorus periscelidactylus Fitch, grape plume moth.	*Apanteles epinotiae*
Lasiocampidae	
Malacosoma americanum (F.), eastern tent caterpillar.	*Monodontomerus subobsoletus*
Malacosoma fragile (Stetch)	*Gambrus ultimus*
Tolype velleda (Stoll)	*Pimpla aequalis*

Host	Parasite
LEPIDOPTERA—Continued	
Phalaenidae	
Acronicta betulae (Riley)	*Mastrus pilifrons*
Alabama argillacea (Hbn.), cotton leafworm.	*Syntomosphyrum esurus*
Anomis erosa Hbn.	*Lixophaga variabilis, Syntomosphyrum esurus*
Arzama obliqua (Wlk.)	*Anachaetopsis tortricis*
Celama sorghiella (Riley)	*Temelucha minor*
Papaipema nebris (Guen.), stalk borer	*Lixophaga variabilis, Macrocentrus delicatus*
Papaipema nebris nitela Guen.	*Lixophaga variabilis*
Stibadium spumosum Grote	*Lixophaga variabilis*
Trichoplusia ni (Hbn.), cabbage looper	*Lixophaga variabilis*
Arctiidae	
Diacrisia virginica (F.), yellow woollybear.	*Tritneptis hemerocampae*
Estigmene acrea (Dru.), salt-marsh caterpillar.	*Tritneptis hemerocampae*
Hyphantria cunea (Dru.), fall webworm	*Syntomosphyrum esurus*
Geometridae	
Coryphista meadi (Pack.)	*Pimpla aequalis*
Lymantriidae	
Hemerocampa leucostigma (J. E. Sm.), white-marked tussock moth.	*Syntomosphyrum esurus, Tritneptis hemerocampae*
Nygmia phaeorrhoea (Donov.), browntail moth.	*Syntomosphyrum esurus*
Porthetria dispar (L.), gypsy moth	*Syntomosphyrum esurus*
Stilpnotia salicis (L.), satin moth	*Tritneptis hemerocampae*
Papilionidae	
Papilio polyxenes asterius Stoll	*Tritneptis hemerocampae*
Papilio sp.	*Arachnophaga frontalis*
DIPTERA	
Tachinidae	
Compsilura concinnata (Meig.)	*Eurytoma appendigaster*
HYMENOPTERA	
Tenthredinidae	
Ametastegia glabrata (Fall.), dock sawfly	*Mastrus smithii*
Diprion hercyniae (Htg.), European spruce sawfly.	*Tritneptis hemerocampae*
Euura salicis-nodus (D.T.)	*Calliephialtes grapholithae*
Macremphytus tarsatus (Say)	*Mastrus smithii*
Braconidae	
Agathis acrobasidis (Cush.)	*Calliephialtes grapholithae*
Apanteles glomeratus (L.)	*Eurytoma appendigaster*
Apanteles lacteicolor Vier.	*Eurytoma appendigaster*
Apanteles melanoscelus (Ratz.)	*Eupelmus spongipartus, Eurytoma appendigaster, Haltichella xanticles*
Apanteles solitarius (Ratz.)	*Eurytoma appendigaster*
Macrocentrus ancylivorus Roh.	*Mastrus pilifrons, Tritneptis hemerocampae, Eurytoma appendigaster, Eupelmus limneriae, E. spongipartus, Arachnophaga frontalis, A. costalis*
Macrocentrus delicatus Cress.	*Eupelmus spongipartus, Perilampus fulvicornis prothoracicus*
Macrocentrus instabilis Mues.	*Eurytoma appendigaster*
Macrocentrus spp.	*Eupelmus limneriae, Arachnophaga frontalis, A. costalis, Encyrtaspis semirufa, Perilampus stygicus, Eurytoma appendigaster*
Meteorus versicolor (Wsml.)	*Eupelmus spongipartus*

Host	*Parasite*
HYMENOPTERA—Continued	
Ichneumonidae	
Campoplex validus (Cress.)	*Eupelmus limneriae*
Gambrus extrematis (Cress.)	*Mastrus smithii, Monodontomerus subobsoletus*
Glypta rufiscutellaris Cress	*Eupelmus spongipartus, Eurytoma appendigaster*
Phobocampe disparis (Vier.)	*Eurytoma appendigaster*
Temelucha minor Cush	*Eupelmus spongipartus*
Chalcididae	
Ceratosmicra debilis (Say)	*Eupelmus limneriae*
ARACHNIDA	
Gnaphosidae	
Gnaphosids	*Arachnophaga frontalis*
Zelotes sp.	*Lymeon orbum*

IMPORTED SPECIES RECOVERED AFTER LIBERATION

Between 1931 and 1935 numerous species of parasites obtained from the oriental fruit moth in Japan, Korea, Europe, and Australia were released in peach orchards in the Eastern United States (Allen et al. *1940*). A smaller number of releases were made from 1935 to 1955. Several of these species were recovered from the oriental fruit moth when it was collected in the field, and some may have become established, although no records proving acclimatization have been published except for *Agathis diversa* and *A. festiva*. The first five of the parasite species discussed below attack oriental fruit moth larvae in peach twigs. *Phanerotoma grapholithae* attacks eggs but is recovered from host larvae. The last two discussed are cocoon parasites.

There were 21 small releases from 1933 to 1937 of *Apanteles molestae* Muesebeck, which was imported from Japan, at widely separated locations from Connecticut to Georgia and west to Michigan and Kentucky. Two adults were reared from peach twigs collected at Williamson, N.Y., 7 days after liberation there.

There were 30 liberations from 1933 to 1937 of *Orgilus longiceps* Muesebeck, which was also imported from Japan, at widely separated locations from Massachusetts to Michigan and south to South Carolina and Arkansas. One specimen was reared from each of two localities at Williamson, N.Y., from twigs collected 7 days after liberation.

Macrocentrus thoracicus (Nees), which is abundant in Japan and Korea as a parasite of the oriental fruit moth, was collected in peach orchards in those countries and released from 1933 to 1937 in many locations from Connecticut to Michigan and south to South Carolina. In 1937 infested twigs were collected from 20 properties shortly after release of the parasites. From three of the properties located at Wixom and Covert, Mich., and Avon Lake, Ohio, seven *M. thoracicus* specimens were recovered from twigs collected 9 to 20 days after liberation of the parasites. None have been recovered subsequently.

Pristomerus vulnerator was imported from Europe, Japan, and Korea. The European material was released in 1932 in New Jersey, New York, and Tennessee. Several adults were recovered from the oriental fruit moth during the same season as the release and several more from *Anarsia lineatella* the

following season, but none from these locations subsequently. The material from the Orient was released in 17 widely scattered locations from Connecticut to Michigan from 1934 to 1937. Two adults were recovered from the oriental fruit moth at Williamson, N.Y., in infested peach twigs collected a week after release there.

Horogenes molestae, which was imported from Japan and Korea, was liberated at 311 locations from Massachusetts to Illinois and south to Georgia and Arkansas from 1932 to 1937. In many places there was a spectacular buildup in the generation immediately after release followed by an abrupt decrease. In 1937 a survey was made of larval parasitism of twigs in 65 peach orchards in Ohio, Indiana, Michigan, and Illinois from 9 to 60 days after liberation. *H. molestae* was recovered throughout the period and from nearly all the properties surveyed. Despite considerable competition from other parasite species, the rates of parasitization for *H. molestae* frequently exceeded 50 percent and averaged 16.3 percent of all the insects reared. In 1939 it was again recovered at nine locations in Indiana, Ohio, and Michigan after persisting for at least 2 years following the last releases there, but it has not been recovered since by workers at the Moorestown laboratory. In 1951 a few specimens of *H. molestae* were received from Japan. After a satisfactory technique was developed for propagating it in *Gnorimoschema operculella* (Allen *1954b*), several thousand adults were released in 10 locations in New York and New Jersey in 1953.

Large numbers of *Phanerotoma grapholithae*, obtained as a parasite of the oriental fruit moth in Japan, were released from 1933 to 1936 in 132 locations from Massachusetts to Indiana and south to Georgia and Tennessee. Shortly after release, one adult was reared from peach twigs collected at Moorestown.

From 1951 to 1955, inclusive, *P. grapholithae* was propagated at the Moorestown laboratory from a few adults received through S. E. Flanders of the California Agricultural Experiment Station from Tsinan, Shantung, China. Flanders stated that the parasite was reared from fruitworms in pear and apple, presumably *Carpocapsa pomonella* mixed with other Lepidoptera. During this period more than 82,000 of these parasites were released in 207 locations from Connecticut to western New York and Virginia. Most of these locations were in neglected apple orchards, where *C. pomonella*, the oriental fruit moth, and *Grapholitha prunivora* were present. About 20 *P. grapholithae* specimens were recovered from these liberations, but usually only one to a collection and during the same season as the release. These were reared principally from *C. pomonella*, although a few were obtained from the oriental fruit moth. The most encouraging recovery was in 1956, when seven of these parasites were reared from as many locations, which had been colonized in 1955 in Connecticut, the Hudson Valley, and western New York.

Gambrus stokesii Cameron, a common parasite of *C. pomonella* and oriental fruit moth cocoons in Australia, was imported in 1932. Small numbers were released in two locations in 1933. One parasite was recovered from an oriental fruit moth cocoon at Moorestown about a week after release there. In 1939 several thousand of these parasites were released in 23 locations from Connecticut to Michigan and south to Georgia. No organized attempt has since been made to study the cocoon parasites

of the oriental fruit moth, and the parasite has not been recovered from the field since 1933.

Perisierola angulata Muesebeck, another Australian parasite of oriental fruit moth cocoons, was imported in 1931. During 1932 and 1933 it was released in 76 locations from Massachusetts to Illinois and south to South Carolina and Kentucky. In 1932 and shortly after these liberations it was recovered from Beverly, Cinnaminson, and Moorestown, N.J., Monsey, N.Y., Bridgeville, Del., and Henderson, Ky.

SPECIES WHOSE RELATIONSHIP TO THE ORIENTAL FRUIT MOTH IS UNCERTAIN

Some species have been recorded in the literature as parasites of the oriental fruit moth, but their relationship to this insect is questionable. Several of them may have been the parasites of some other host, and they were inadvertently included in material with the oriental fruit moth and incorrectly associated with it. This error could easily have occurred when numerous collected specimens were reared and no effort was made to isolate the hosts and to check back to the remains from which the parasites issued. Where only single parasite specimens were reared, even though the oriental fruit moth was the true host, the rarity of parasitism would prove it to be accidental and of no particular consequence. Several other species are obviously misidentifications.

Those recorded species whose relationship to the oriental fruit moth is uncertain are as follows:

Actia interrupta Curran
Actia pilipennis Fallén
Agathis conspicua (Wesmael)
Apanteles aristoteliae Viereck
Apanteles epiblemae Muesebeck
Apanteles harti Viereck
Bracon hebetor Say
Campoletis argentifrons (Cresson)
Campoletis patsuiketorum (Viereck)
Chaetochlorops inquilina (Coquillett)
Cubocephalus alacris (Cresson)
Elephantocera greenei Townsend
Eubadizon gracile Provancher
Eurytoma tylodermatis Ashmead
Exidechthis nigricoxalis (Cushman)
Glypta phoxopteridis Weed
Glypta varipes Cresson
Glypta vulgaris Cresson
Goniozus columbianus Ashmead
Ichneutidea proteroptoides Viereck
Lampronota sesiavora (Rohwer)
Leskiomima tenera (Wiedemann)
Meteorus hyphantriae Riley
Miotropis clisiocampae Ashmead
Paraolinx nigriventris (Girault)
Phanerotoma tibialis (Haldeman)
Phorocera erecta Coquillett
Rogas platypterigis Ashmead
Spilochalcis flavopicta (Cresson)
Triclistis fulvipes (Cresson)

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[1] Entries with an asterisk (*) refer to parasitism in the oriental fruit moth.

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